NOTES ON
GALVANISM
AND
FARADISM

MAGILL

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NOTES ON GALVANISM AND FARADISM

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BY

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SECOND EDITION
(REPRINTED)

WITH 67 ILLUSTRATIONS

LONDON
H. K. LEWIS & CO. LTD.
1921

First Edition	*March* 1916
Reprinted	*September* 1916
,,	*May* 1917
Second Edition	*March* 1919
Reprinted	*February* 1921

PREFACE

The present volume in no way aims at competing with the many exhaustive works dealing with the theoretical aspect of Medical Electricity. It is intended simply as an introduction to a very difficult subject, and is mainly for the use of masseuses preparing for the examinations in Medical Electricity now held by the Incorporated Society of Trained Masseuses. For this reason the more complicated forms of apparatus, *e.g.* diathermy, high frequency, etc., have been omitted.

The certificated masseuse is bound by the rules of the above Society to work only under the direct supervision of a registered medical practitioner. It has not therefore been thought necessary to enter to any extent into the pathological and symptomatic aspects of the diseases mentioned; still less to point out the evil results attendant upon erroneous methods of treatment; for it is assumed that the patients are adequately protected by the fact that the doctor prescribes the form of treatment desirable, modifying the same when time and progress make modification necessary.

I have endeavoured to avoid, as far as possible, explanations requiring an extensive knowledge of mathematics, physics, and chemistry, and to make use of ordinary rather than technical terms. Where feasible, simple explanations have been adopted and more complicated ones omitted; for example, the polarisation of a cell has been attributed entirely to increased resistance and the question of a back E.M.F. avoided; also, the plates of a cell have been regarded as of the same potential throughout, in accordance with the usage of many text-books on technical electricity. This avoids the difficulty which many students find of considering the plate to be of one potential in the electrolyte and of the opposite potential at the upper end.

I am much indebted to Messrs. Schall & Son and to Messrs. H. K. Lewis & Co. Ltd. for the kind loan of blocks for many of the illustrations; and my thanks are also due to the Incorporated Society of Trained Masseuses for permission to insert the syllabus and previous examination questions to be found in the Appendix.

E. M. MAGILL.

9A GLOUCESTER PLACE,
PORTMAN SQUARE, W.
March, 1916.

NOTE TO SECOND EDITION

THE second reprint of this book being exhausted, the Author has taken the opportunity of the issue of a new edition to make a number of alterations and some additions in the text which it is hoped make the meaning clearer and the teaching more easy to follow, besides bringing it up to date. Another Examination Paper has also been included.

9A GLOUCESTER PLACE,
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March, 1919.

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NOTES ON GALVANISM AND FARADISM

PART I

GALVANISM

CHAPTER I

GENERAL CONSIDERATIONS

Introduction.—It is, at the present time, still impossible to give a definition of electricity. The actual nature of electricity is unknown.

The science of electricity is based upon the study of the various phenomena produced by this form of energy.

The word "electricity" gives the impression of a material substance. In all probability this is an erroneous conception. Electricity is not a form of matter; it cannot be seen, it has no colour, no form, no weight. It is thought to be some form of motion. It may conveniently be compared with that other common form of energy, heat. Everyone is perfectly familiar with heat and its manifestations. It is quite usual to allude to heat as a substance; we speak of giving heat to an object and of taking heat away. Yet it is clear that heat is not a substance, but a condition or state. The more active the movements of the particles of any substance, the hotter that substance appears; the less the movement, the colder the substance. When a substance is heated, it merely means that its particles have been thrown into violent vibration by some means, such as friction or chemical action. Heat, therefore, may clearly be regarded as a condition; and in the same way we must regard electricity.

The One-Fluid Theory.—There are many theories concerning the nature of electricity, but the simplest way to form a conception of this intangible subject is to make use of the old *one-fluid theory* of Benjamin Franklin. This is no longer accepted in its entirety, but until a greater degree of scientific accuracy can be obtained, the use of such a supposition is permissible.

The one-fluid theory supposed that all the material substances of the universe—earth, air, water, the bodies of men and animals, inanimate objects—were permeated with a fluid, colourless, odourless, imponderable, a fluid so attenuated that it escaped all recognition by our senses and by scientific investigations. Only when this fluid was disturbed in some way did it become apparent.

Thus, if a large excess of it were loaded upon any object, that object showed certain peculiar and abnormal characteristics; if the normal quantity were taken from another object, that object, having a deficit, also showed extraordinary properties. When the fluid was thrown into motion, other manifestations appeared in the neighbourhood of the stream.

Thus, although electricity is always present in every substance, it is only when the fluid is disturbed in some way that we are conscious of its existence.

Positive and Negative Electrification.—According to this old theory, a substance which has received an excess of the electric fluid is said to be in a state of positive electrification or to be positively electrified or excited.

A substance which has lost its normal quantity of the electric fluid is said to be negatively electrified.

Substances having either an excess or a deficit are spoken of as being "charged" or "excited," for both are charged with the power of producing those manifestations which we are now accustomed to associate with the word "electricity."

The Standard of Electrification.—We have spoken of substances having an excess or a deficit of electricity, that is, having more or less than the normal amount which is constantly present in all matter. This brings up the question, "What is meant by the normal amount?"

A standard of comparison is thus necessary: just as, when speaking of heat, we need a standard of temperature; or in speaking of height, a standard of level.

In the case of heat, the constant with which we compare the temperatures of various substances is the melting-point of ice—*i.e.* 0° Centigrade. To ascertain the height of mountains or the depth of mines, the fixed point from which measurements are taken is sea-level, for this is the most unvarying level we have. Similarly, we require some similar unvarying constant from which we can measure states of electrification. This standard is found in the electrical condition of the earth. The electrification of the earth is unvarying. The earth cannot be made positive or negative; nothing we can do to it has any apparent effect upon its electrical condition.

Electrical Disturbances.—It is already understood that unless this hypothetical fluid is disturbed from its normal state of equilibrium in the material substances of the universe, we are not conscious of its existence.

There are various ways in which it can be disturbed.

when it may be made to produce what is called Static Electricity and Current Electricity.

Static Electricity.—When any object is either positively or negatively charged, we speak of the electrical disturbance thus produced as Static Electricity—that is to say, electricity made manifest but standing still.

Although the electricity is standing still, it is nevertheless in a state of tension.

The excess of electricity in the positively charged body is constantly endeavouring to run away in order that the object may again be normal. If there is a suitable path for it, away it will run, just as water in a high-level reservoir will flow down to sea-level if provided with outlet pipes.

Similarly, the object with the deficit of electricity is constantly clamouring for its due amount; in order to obtain this, it will, if possible, seize more from all its surroundings. Just as the water from the ocean will flow into the moat of a child's sand-castle, so electricity will flow from earth and objects in contact with earth into the negatively charged body.

Current Electricity.—Current electricity is defined as electricity in motion. Electricity is set in motion because of the desire of the electric fluid to find its own level.

If a positively charged body be connected with earth or to a negatively charged body by a suitable conducting material, electricity will run from the highly charged body to the one in the lower state of electrification, until the fluid is equally distributed between the two. Then the flow ceases, but we have had present a momentary current of electricity.

Sparking is produced in the same way. Imagine the positively charged body to be brought closer and closer to the negatively charged body. The tension between the two electrifications becomes greater and greater, until finally the electricity can bridge the gap of air between the two substances. A spark occurs; at that moment the fluid has distributed itself equally between the two objects, which have then become normal, or been discharged.

In this chapter we have made use of the one-fluid theory for the sake of convenience. But let it be clearly understood that this method of speaking is not strictly accurate. The one-fluid theory is now replaced by the Electron Theory. It seems wiser, however, to defer a consideration of this more complicated conception to a later chapter, especially as the present terminology of Medical Electricity is yet based upon the older theory.

CHAPTER II

STATIC OR FRICTIONAL ELECTRICITY

Methods of Production of Electricity.—Although we speak of the production of electricity, yet we do not produce or create any new thing. All we do is to disturb in some way the normal distribution of the electric fluid. There are three chief ways in which electricity can be made manifest:

1. By friction.
2. By chemical action.
3. By induction.

Each of these will have to be considered separately and in detail, as they are each made use of for the purposes of medical work.

Electricity produced by Friction.—This is of historical interest. By means of friction the first glimmerings of this long-hidden potentiality came to light. It was about 600 B.C. that the Greek philosopher Thales of Miletus made the astonishing observation that a piece of amber, rubbed vigorously with a dry cloth, acquired new and transient properties. It had the power of attracting to itself all manner of small, light objects, like scraps of wool, silk, cork, etc. These scraps adhered to the amber firmly for a moment, and were then as vigorously repelled, only to be re-attracted after having touched earth. The amber, held close to the knuckle,

no doubt surprised the philosopher by sparking, after which it lost its powers of attraction; these could, however, be regained by friction.

I do not know what the early inquirers made of these observations, but apparently the outer world was not impressed with the importance of the discoveries, for no new developments took place until the time of Queen Elizabeth. In the year 1600 Dr. Gilbert of Colchester produced a treatise "De Magnete," in which he described various experiments he made on the same lines as Thales. It is to the ancient Greek that we owe the word "electricity," which is derived from *elektron*, meaning amber.

Simple Experiments in Frictional Electricity.—There are many well-known classical experiments which teach much about electricity. They are very simple and should be performed by every student.

Let it be first stated that when *any* two dissimilar substances are rubbed together for a considerable time and with sufficient energy, the hypothetical electric fluid is disturbed. One of the substances takes an excess; the other substance is left with a corresponding deficit; both are charged with various new powers. The charging remains obvious for a variable length of time, according to the nature of the substances used in the experiment. Some substances allow electricity to flow through them very rapidly; others offer more or less obstruction to the flow.

The substances offering an obstruction retain the charge long enough for simple experiments to be made. Such substances are called non-conductors. Those along which electricity flows rapidly do not retain the charge long enough to show abnormal properties; they are called conductors.

In the days of Dr. Gilbert, the substances which retained their charges were called electrics; those which allowed the charges to run away were called non-electrics. It was then thought that non-electrics were non-electrifiable. We now know that *all* bodies are electrics if suitable precautions are taken to prevent the dissipation of the charge.

So it can be safely said that when *any two dissimilar* bodies are rubbed together, electrical separation occurs.

In all the following experiments it is absolutely necessary for success that all the substances used should be perfectly dry. A wet day should always be avoided for performing friction experiments. The reason for this is that water is an excellent conductor of electricity; if there is a slight coating of moisture on any of the substances, the charges will rapidly escape along this to earth.

I. Take a rod of vulcanite, ebonite, or sealing-wax, and rub it vigorously for a few minutes with a piece of dry warm flannel. The rod will then be found to possess new properties; it is charged, or excited, or electrified.

(*a*) Held over small fragments of paper, silk, cotton, etc., it attracts these. They fly up to it, cling for a moment, and then fly back to earth, only to be again attracted. This alternate repulsion and attraction may be repeated many times.

(*b*) Held near the face, the rod conveys the feeling of cobwebs.

(*c*) If sufficiently electrified, it will emit crackling noises and sparks when held close to a knuckle. After this sparking, the rod is discharged; it no longer possesses any attraction for scraps of paper.

In this experiment it is to be supposed that the friction between the rod and the flannel has resulted in a separation of the electric fluid present in the two. The rod is regarded as having a deficit; it is said to be negative.

The flannel is equally electrified but positively. This is a convention, and must be taken for granted.

Negative electricity is sometimes called Resinous Electricity, because resin and allied substances are all affected in the same way by friction with flannel or fur.

II. A glass rod rubbed with silk shows similar properties to the rubbed sealing-wax. In this case it is assumed that the glass has become positively and the silk negatively electrified. Positive electricity is therefore sometimes called Vitreous Electricity. It may seem odd that it is assumed that the glass is positively electrified, seeing that it displays the same characteristics as the electrified sealing-wax. It can, however, be proved that glass and sealing-wax, though both excited, are nevertheless in different electrical conditions by the following experiments.

III. Suspend the electrified glass rod in a wire stirrup which hangs by a silk thread from some convenient support. When quite steady, bring the well-excited sealing-wax close to it, end to end, but without actual contact. The sealing-wax attracts the glass, and the latter will follow all the movements of the former.

IV. Now bring close to the suspended glass rod a second similarly electrified glass rod. Mutual repulsion takes place. It may be logically assumed that the two glass rods are similarly charged if they have been rubbed with the same piece of silk.

Thus, we are brought to one of the fundamental principles of electricity—"Bodies with like charges repel each other," or, stated more briefly—"Like electricities repel."

As we have seen, glass and sealing-wax attract each other, whereas glass and glass repel. It must be concluded, therefore, that the glass and sealing-wax have been differently electrified.

Thus follows the second great principle—"Bodies with unlike charges attract each other," or "Unlike electricities attract."

V. The next experiment also demonstrates the mutual repulsion of like electricities. Take a sheet of foreign notepaper and hold it firmly on a well-warmed wooden board. Rub the paper very briskly for a few minutes with a warm dry clothes-brush.

Then quickly, with a sharp knife, cut the paper into fine strips, leaving a margin intact, in such a way that the strips are still held together by a thin edge of paper. On doubling up this thin edge, the strips will open out into a tassel, each strip repelling its neighbours. All the strips must be in the same state of electrification. This shows that like electricities repel each other.

VI. Hair brushing is also a good example of electrification produced by friction. The brush receives one kind of charge, the hair an equal and opposite charge. On dry days it may be frequently noticed that the hair is strongly attracted to the brush, winding itself around in a most annoying manner and emitting crackling sounds. This is caused by the attraction of unlike electricities. Also, it is to be seen that every hair fiercely repels its neighbours, which are similarly electrified.

VII. If the friction experiments are repeated with a metal rod instead of glass or sealing-wax, no change can be detected in the metal, owing to the fact that the charge is rapidly transmitted through the metal and the experimenter's hand to earth before there is time for the demonstration of the charge. But if the metal rod be insulated by means of a wooden handle, it can be electrified by friction just as readily as glass or sealing-wax.

Conductors.—Those substances which allow electricity to flow readily through them are called good conductors. They are synonymous with the non-electrics of Gilbert. Substances vary very much in the way they conduct electricity, but the following list comprises some of the best in the order of their conductivity:

Silver
Copper
Gold
Aluminium
Zinc
Iron
Tin
Mercury
Carbon
Acids
Solutions of metallic salts
Water
The body

Partial Conductors.—These are substances which offer a considerable obstruction to the flow of electricity, but do not quite block it:

Linen
Cotton
Wood
Stone
Marble

Insulators.—These are substances which oppose so much obstruction to currents of ordinary force that they are completely blocked. They are:

Oils
Leather
Wool
Silk
Sealing-wax
India-rubber
Shellac
Vulcanite
Amber
Glass
Dry Air

Resistance.—The obstruction which bad conductors offer to the flow of electricity is usually called resistance.

All substances offer some resistance, but in the case of good conductors it is very little; in the case of silver and copper, it is practically negligible. That is why copper is used for electric-light cables and the conducting cords of batteries.

Insulation.—This is a term used to express the condition of a charged body when completely surrounded by bad conductors in such a way that the charge cannot escape.

Copper cables used for electric-light mains are insulated by coverings of rubber and silk.

CHAPTER III

STATIC ELECTRICITY IN MEDICAL WORK

FROM the time of Dr. Gilbert until the middle of the eighteenth century, a hundred and fifty years later, very little advance was made in the knowledge of electricity.

It was about 1750 that Benjamin Franklin, then working in Philadelphia, began to use static electricity in the treatment of paralytic cases. This form of electricity is sometimes called Franklinic electricity in recognition of his work. From his time onwards, through the eighteenth and nineteenth centuries, static treatments were used to a considerable extent in various London hospitals for the different kinds of paralysis, hysteria, and various functional diseases. The method was to give shocks to the patient by means of rudimentary static machines.

A static machine is a piece of apparatus in which positive and negative electrifications are produced in certain parts, called poles, by means of friction. From these poles a positive or a negative charge can be given to a patient through suitable conductors.

The Wimshurst Static Machine.—This is the most satisfactory piece of apparatus for the Franklinic treatment. Although called a static machine, its mode of action is chiefly inductive.

It consists of glass plates, upon which are mounted a number of radiating brass discs.

The circular glass plates are arranged upon an axle and are made to revolve in opposite directions either by hand or by some motor power.

In contact with the plates are stationary brushes. As the plates revolve contact takes place between the brass segments and the brushes, with the result that positive and negative charges are received by the brushes as long as the plates revolve.

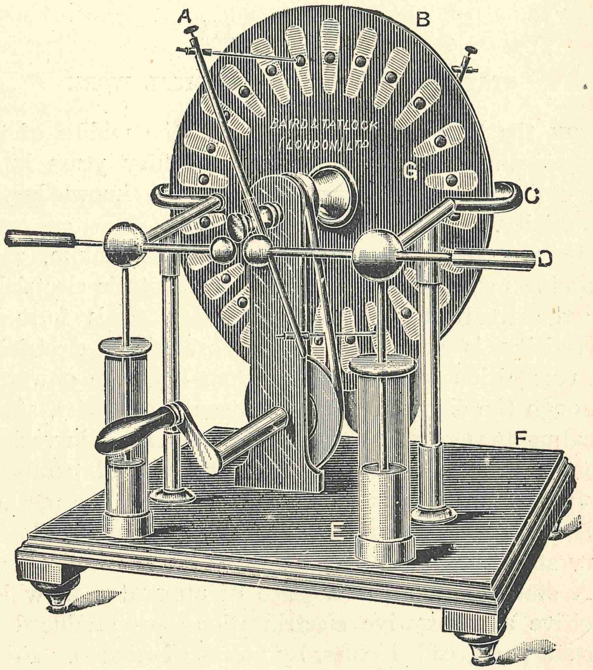


FIG. I.—THE WIMSHURST MACHINE.

By means of suitably arranged conductors, the positive electricity is carried to one pole, the negative to the other.

The whole machine and its conductors are insulated from earth to prevent escape of the charges.

The patient may be connected with one or other pole, and then receives a charge, positive or negative, according to the pole used. In order that he may retain the charge, he also must be insulated during the treatment. This is effected by means of a glass platform upon which the patient is placed.

As the various methods of application can only be understood by the use of the actual machine, nothing further will be said in this place, beyond an enumeration of the uses to which static electricity has been put in medicine.

In the early days, before current electricity was applied to pathological conditions, shocks from the static machine were given for muscular wasting; paralytic cases are now more usually treated by Galvanism and Faradism.

At the present time static treatments are given for functional nerve diseases, such as Hysteria, Neurasthenia, Insomnia, Nervous Headaches, and obscure Neuralgias.

Static applications have the effect of raising the blood-pressure and give most beneficial results in cases where this is abnormally low.

It should not be given where the blood-pressure is already abnormally high.

It may be observed here that all static machinery must be kept very dry. It gets speedily out of order in this damp climate. Perhaps this accounts for the fact that this method of treatment has fallen to some extent into disuse in England. It is much more popular in America.

CHAPTER IV

CURRENT ELECTRICITY

So far only static electricity has been considered.

Electricity in motion, or current electricity, is of greater importance and use in medicine.

The Electric Current.—From the previous chapters it will be readily understood that if a substance with an excess of electricity be connected by a good conductor with a substance in a lower state of electrification, electricity will flow from the higher to the lower level until both substances are equally electrified.

This flow along the conductor constitutes the electric current.

The flow of electricity may be compared with the flow of heat from a hot to a cold substance; or with the flow of water from a high to a low level.

Potential.—If an insulated positively charged body be connected with earth by a good conductor, its surplus charge flows to earth and the body becomes "neutral."

The flow took place from the body to earth, because the electric pressure of that body was above that of the earth. This is usually expressed by saying that the body was at a higher *potential* than the earth.

Similarly, if a negatively charged body be earthed,

electricity flows from the earth to the body, until its deficit is made up again and it becomes neutral. The body, when negatively charged, was at a lower potential than the earth.

Electricity will always flow from a body at a high to a body at a lower potential, and the flow will continue until equality of potential is established, when it will cease.

If a flow is to be maintained—that is to say, if a current is to be kept running for any length of time—some method must be used which will keep up the potential difference. In the case of the static machine, this potential difference was kept up between the two poles by means of friction. If the poles had been connected a current would have been obtained between them along the connector.

The two other common methods of producing a potential difference are chemical action as utilised in an electric cell; and induction, which is the principle upon which the dynamo is based, both of which will be considered later.

Electro-motive Force.—This may be taken as being synonymous with the potential difference which can be maintained by any generator of electricity. It is an expression frequently used in connection with cells, batteries, and dynamos. The greater the potential difference between the two poles of the electric generator, the greater will be the " force that moves the electricity." This may be compared with a water flow. The greater the difference of level between two masses of water, the greater will be the hydraulic pressure exerted by the water at the high level.

Voltage.—This is a word used to indicate the force with which the current, produced by a certain potential difference, will flow along its conductor. The greater the potential difference of the generator, the greater will be the voltage of the current produced. Voltage and electro-motive force, shortly described as E.M.F., are very often regarded as synonymous, and are used loosely to convey the same idea, that is, the force with which a current flows.

Comparison with a Water System.—If there should be any difficulty in grasping these somewhat abstract conceptions, a common simile may be taken.

Imagine a cistern full of water to be placed at a high level. So long as there is no outlet for the water, this remains at rest in its tank. Compare this with a body positively charged, *i.e.* at a high potential.

If a pipe be now arranged from the high-level tank to a low-level tank, the water will flow along the pipe with a certain force. Compare this with the current of electricity flowing from a positive to a negative body.

The flow of water depends upon the difference in level of the two tanks. This is comparable with the potential difference or the electro-motive force.

The strength or force with which the stream of water flows is directly dependent upon the amount of difference in the two water levels. The pressure of the stream of water is comparable with the force or voltage of the electric current.

To continue the simile, as soon as the high-level cistern is emptied, the flow of water ceases. It is only possible to have a continuous flow of water if we have some means of keeping the cistern filled, *e.g.* by a pump. So it is with electricity. In order to maintain a continuous current, we must have some means whereby one body, at the end of a conductor, may be kept constantly charged positively, and a second body at

the other end of the conductor constantly charged negatively.

The three chief ways by which this potential difference can be maintained have already been mentioned—friction, chemical action, and induction.

CHAPTER V

CHEMICAL ACTION AS A PRODUCER OF POTENTIAL DIFFERENCE

It is impossible in a simple textbook to enter into an explanation of the mode of action whereby chemical changes result in electrical separation.

It must be taken for granted that whenever two suitable chemicals interact with each other to form new substances, the electricity which was dormant in them becomes separated; one of the substances receives an excess and becomes positively charged, while the other substance shows a deficit and is negative. Thus a difference of potential is set up between the two. This potential difference is maintained as long as chemical action continues. Chemical action may therefore be regarded as a pumping force constantly raising one substance to a higher potential than the other.

The potential difference thus established varies very much with the substances chosen. It depends largely upon the violence of the chemical activity. To take a concrete example:

A piece of zinc immersed in dilute sulphuric acid is violently attacked by the acid and vigorous chemical action takes place. The liquid becomes hot, bubbles of gas make their appearance, and the zinc is gradually dissolved. The acid combines chemically with the

zinc forming a new substance in which both acid and zinc take part: this is called zinc sulphate. It disappears from view because it is very soluble in the fluid. At the same time bubbles of hydrogen gas are set free from the acid. The chemical change is represented by the following equation:

$$Zn + H_2SO_4 = ZnSO_4 + H_2.$$

$$\text{Zinc} + \text{Sulphuric Acid} = \text{Zinc Sulphate} + \text{Hydrogen}$$

During this chemical exchange, electrical separation also occurs. That part of the zinc which dissolves in the acid carries a positive charge to the fluid, and the zinc plate still undissolved suffers from a deficit and is therefore negatively charged. Thus a potential difference is set up between the zinc and the fluid and is maintained as long as the chemical action continues. The positive charge may endeavour to escape back from the fluid to the zinc in order to equalise the potential, but this is entirely prevented by the continued pumping action of the chemical exchange.

In order to make use of the negative and positive charges in the production of a current, it is necessary to supply some path along which the positive electrification may flow undisturbed from the fluid to the zinc. This is usually accomplished by placing a second metal plate in the fluid and attaching the upper free end of this plate by a conducting wire with the upper free end of the zinc. A clear unobstructed conducting circuit is thus established along which the electricity can flow from the positively charged acid to the negatively charged zinc.

It should be pointed out here that the second metal plate must be of such a nature that the acid does not act upon it to any extent. Its rôle is a passive one, being merely that of a conducting path. Such a plate is frequently called the indifferent plate, whereas the plate at which the chemical action takes place is called the active plate.

An arrangement such as the above, in which potential difference is maintained between two substances, is called a Galvanic or Voltaic cell.

The student should make a simple cell of this sort, and observe the changes which occur.

The Simple Voltaic Cell.—This consists of the following essentials:

1. Two different metal plates.
2. A chemical solution capable of combining readily with one but not with the other metal.
3. A conducting wire to connect the two plates.
4. A containing vessel of glass or earthenware.

The Metals.—The two most commonly chosen for the simple cell are zinc and copper. A carbon plate is occasionally used instead of the copper, as no solutions act upon it chemically.

The Chemical Solution.—This must be of such a nature that it will combine with one of the metals and not at all or to a much less extent with the other. It must also be a good conductor of electricity.

Usually a dilute solution of hydrochloric or sulphuric acid is chosen.

Such a solution, which conducts electricity by its own decomposition, is called an electrolyte.

In order to arrange the cell, almost fill the vessel with the electrolyte. In this the two metals are to be partially immersed in such a way that they do not touch each other. Their upper ends, which project above the electrolyte, are to be connected by the conducting wire.

After a short time bubbles will be seen collecting in the electrolyte, and making their way to the copper plate, upon which they are deposited. These are bubbles of hydrogen which have been displaced from the acid by the zinc as it dissolves. They indicate that chemical action is taking place.

Simultaneously, the zinc plate is becoming negative and the fluid positive: the copper, being immersed in a fluid which is positive, also shares its electrification.

As soon as the connecting wire is placed between the positive copper and the negative zinc, electricity will flow along it in the endeavour to again establish equilibrium. This endeavour will be frustrated, because, so long as any chemical action takes place, the zinc plate will be kept negative. Thus a constant current is maintained along the wire from copper to zinc. At this juncture we may notice that the portion of the metal immersed in the fluid is generally called the plate, while that part projecting above the fluid is called the pole.

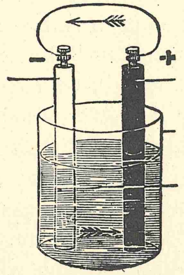


FIG. 2.—SIMPLE VOLTAIC CELL.

The positive pole is also called anode, and the negative pole kathode.

Oersted's Experiment.—The current produced by the simple voltaic cell described above is too weak to be felt through the unbroken skin. Its presence may be detected by means of Oersted's experiment.

Place a compass needle so that it points steadily north and south. Bring the wire carrying the current immediately over and parallel with the needle. If the current is at all strong the needle will be deflected from its north and south position and will tend to set itself at right angles with the wire. The effect of the current upon the needle is produced by what is known as a magnetic field, an influence set up in the neighbourhood of such a current. This will be considered in more detail later when Magnetism is being considered.

Ampère's Rule.—The above experiment has been further elaborated by Ampère, who found that it could be used in order to find out the direction in which the current is flowing in the wire.

You are to imagine the compass needle to be deflected at right angles to the wire. Then imagine a miniature man swimming in the wire in such a position that he is looking at the needle and his left hand is pointing to the north pole of the needle. According to Ampère, the current is then flowing from his feet to his head.

Other Simple Galvanic Cells.—The cells which produce the constant current are named after Professor Galvani of Bologna, who first made experiments with current electricity about the year 1786.

It is interesting to note that it was the Professor's wife who first set his feet upon this trail.

We are told that in her kitchen one day she was preparing a dish of frogs' legs. These were hanging upon a zinc hook. Whenever the tissue was touched with a steel knife, she noticed curious twitching of the muscles.

She drew her husband's attention to this phenomenon, and he began to look into the matter.

It appears that such a preparation of frogs' muscle constitutes a simple cell.

Such muscles soon become filled with acid solutions; these constitute the electrolyte. The zinc hook and the steel knife form the two dissimilar metal plates. In this simple cell, currents were generated strong enough to set up muscular contractions.

Another simple cell can be improvised by means of a lemon and two dissimilar metals, such as a steel needle and silver pin thrust into the fruit. When these are connected by a wire, a small current is produced which can be detected by a delicate measuring instrument called a Galvanometer.

Another simple cell is formed when two different metals are placed on the tongue. The saliva is the electrolyte, and the current produced is manifested by the strong metallic taste in the mouth.

An Electrical Series.—Any two dissimilar metals immersed in an electrolyte result in some degree of electrical separation, but the amount of potential difference set up varies very much according to the pair of metals chosen. It depends to some extent upon the violence of the chemical action on the one metal and the quiescence of the other.

A series can be drawn up in such an order that any metal coupled with one preceding it on the list will be the positive pole, whereas any one coupled with one succeeding it will be the negative pole.

Zinc
Lead
Tin
Copper
Silver
Platinum
Carbon

It will be observed that the greatest potential difference is set up when zinc is coupled with carbon. This explains why these two substances are so frequently found in the cells now on the market.

CHAPTER VI

GALVANIC CELLS

THE simple galvanic or voltaic cell is no longer used, except for demonstration purposes. It has a very serious drawback. If kept running for a short time, the current quickly becomes weaker and weaker, finally ceasing altogether. This can be shown by Oersted's experiment, for the compass needle ceases to be deflected as the strength of the current diminishes. This cessation of the current is due to what is called polarisation.

Polarisation.—The polarisation of a galvanic cell is due to the collection of hydrogen bubbles, which soon thickly coat the copper plate. This layer eventually becomes sufficiently thick to act as a barrier to the flow of the current. It will be remembered that air was classed as an insulator. All gases act in this way. The copper plate finally becomes completely insulated by the layer of gas, which thus blocks the circuit.

Depolarisation.—The cell may be depolarised by taking the positive plate out of the electrolyte and wiping away the bubbles every time they collect. This is a troublesome proceeding, and is now superseded by other methods in which the cell automatically prevents the accumulation of gas.

The improved or constant cells have some chemical substance added to the electrolyte which has the power of absorbing the gas before it can coat the positive plate. This substance is called a Depolariser.

COMMON TYPES OF CONSTANT CELL

There are many varieties of the constant cell on the market. Every electrician of note has devised one or more, and these are frequently named after the inventor. It is impossible to describe more than a few of the commoner ones here. The following, being of use in medical work, are chosen:

1. Cells of the Leclanché type.
2. The Bichromate cell.
3. The Daniell cell.

1. **The Leclanché Cells.**—These are of two kinds, the wet and the dry. The wet one must be familiar to all; it is the cell used so largely for the purpose of operating electric bells. It is composed of the following parts:

1. A square glass jar.
2. An amalgamated zinc rod.
3. An electrolyte of sal ammoniac solution.
4. A depolariser, manganese dioxide, contained in a porous pot.
5. The positive pole, a carbon rod, in the centre of the porous pot.

The containing glass vessel is usually made square, in order to pack more readily into cupboards, etc.

The zinc rod must be well amalgamated. Amalgamation consists in rubbing the metal all over with mercury, until it becomes smooth and silvery-looking.

If the zinc is not amalgamated it becomes used up much more quickly. Commercial zinc is full of impurities; it is also unequally annealed, some parts being softer than others. Owing to these two facts, areas of different potential are set up between the various parts of the zinc plate and local currents occur even when the poles of the cell are not connected. These currents are wasted in the cell, and are also harmful in that they cause a rapid disintegration of the zinc plate. Amalgamation consists in the formation of a smooth homogeneous mixture of mercury and zinc, this mixture being called an amalgam. The amalgam, being homogeneous, will remain at the same potential through the whole extent of the plate. Thus local currents are prevented.

A new amalgamated zinc rod fitted with a terminal can be bought at electrical shops for a few pence. A new rod should be substituted when the old one becomes corroded.

The electrolyte is a solution of sal ammoniac—that is, ammonium chloride. It should fill the jar three-quarters full. When the water evaporates, more may be added. When the sal ammoniac is used up and the cell no longer works, the electrolyte may be renewed by dissolving 6 oz. of sal ammoniac crystals in a pint of hot water.

Some of the electrolyte gradually penetrates through the porous pot, soaking the manganese dioxide, and forming a good conductor for the passage of the current.

The upper inch or so of the glass jar is usually brushed over with some preparation of paraffin wax. This is to prevent "creeping" of the salts. All parts of the cell must be kept thoroughly clean, especially the terminals of the two poles. When the zinc rod becomes coated with a deposit of crystals, these should be scraped off.

The chemical changes that occur in the Leclanché cell are:—

The ammonium chloride unites with the zinc forming zinc chloride, which becomes dissolved in the fluid, and liberating ammonia gas and hydrogen gas.

$$Zn + 2NH_4Cl = ZnCl_2 + 2NH_3 + H_2.$$

The ammonia mostly escapes into the atmosphere.

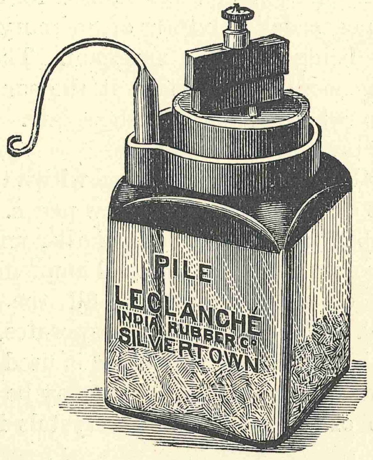


FIG. 3.—THE WET LECLANCHÉ CELL

The hydrogen passes through the electrolyte, enters the porous pot, and is oxidised to water by the manganese dioxide.

Advantages of the Wet Leclanché.—1. It is constant and reliable, provided it is not used too continuously. If this happens, the gases are liberated more quickly than the depolariser can deal with them. If the cell be allowed to rest for a few days, this will right itself, and the cell will be restored to a further period of activity.

2. It can be easily cleaned and renewed without the help of the electrician.

3. It lasts for a considerable time.

4. It has a fairly high E.M.F.

The disadvantage for medical batteries lies in the fact that it is not portable.

Dry Cells of the Leclanché Type.—These have quite replaced the wet cell for medical batteries.

They are made on the following lines:

1. The negative plate is composed of a zinc cylinder to which is soldered a wire terminal. This also acts as the container of the electrolyte.

2. The electrolyte, sal ammoniac, is made into a thick paste with water, plaster of Paris, and glycerine. This lines the zinc cylinder.

3. The depolariser is also solid, being a mixture of sal ammoniac, glycerine, and manganese dioxide. This entirely surrounds the positive plate, and is closely packed in a cotton bag, the whole fitting into the zinc cylinder.

4. The positive pole is a carbon rod in the centre.

The cell is closed up by means of sealing-wax or paraffin-wax, leaving only the two terminals exposed.

Advantages of the Dry Cell.—1. As the various constituents are all solid, these cells are portable, and will work in any position.

2. They are very reliable and do not require attention.

The disadvantage is that they are not renewable. Their working life depends upon the original amount of chemicals present. When this is used up, the cell must be discarded and replaced by another. They vary in size and in length of life, but not in power. Their price is determined by their size, varying from 9*d*. to 2*s*. 6*d*.

The Bichromate or Chromic Acid Cell.—This is frequently, but not invariably, bottle-shaped. The container is a glass flask fitted with a suitable lid; through this pass the poles. The negative pole is a zinc rod. The positive pole is formed by two carbon plates, one on each side of the zinc. The two carbons are connected together.

The electrolyte is sulphuric acid. Mixed with it is the depolariser, a solution of bichromate of potash. The fluid thus formed is yellow.

The sulphuric acid acts upon the zinc, forming zinc sulphate and liberating hydrogen. The hydrogen is oxidised to water by the bichromate. When the depolariser has lost its power, it becomes a dirty green, and must then be renewed. A fresh solution can be made up in the following proportions:

Potassium Bichromate	6½ oz.
Concentrated Sulphuric Acid . . .	6 oz.
Water.	35 oz.

Make the bichromate of potash into a solution with the water, and *very gradually* add the acid to it, stirring all the time. If the acid is added suddenly, or if the water is added to the acid, a violent explosion occurs. The concentrated acid burns the skin and clothes at once. A strong solution of ammonia should always be at hand in order to neutralise the acid when dealing with these cells.

When not in use, the zinc rod must be removed from the electrolyte; otherwise, the zinc is very rapidly dissolved by the strong acid. A device in the lid is usually supplied for readily lifting the poles out of the fluid.

Advantages of the Acid Cell.—1. It has a high E.M.F.

2. It is a single-fluid cell, having no porous pot to impede the current; therefore its resistance is low.

3. It can produce a strong current for a short time, and is usually used for heating cauteries.

4. It is easily refilled and kept in order.

Disadvantages.—1. Intermittent action.

2. Want of portability.

3. The danger of spilling the very corrosive acid.

The Daniell Cell.—This may be taken as an example of a two-fluid cell, one fluid being the electrolyte, and the other the depolariser.

It consists of the following parts:

1. A copper vessel, which acts both as container and positive pole.

2. The negative pole, which is an amalgamated zinc rod in the centre of the cell.

3. Inside the copper cylinder and encircling the zinc rod is a porous pot, separating the two fluids.

4. The exciting fluid is a solution of sulphuric acid, placed inside the porous pot. This acts on the zinc rod.

5. Outside the porous pot and in contact with the copper cylinder is a saturated solution of copper sulphate, which acts as depolariser. This solution is kept saturated by the presence of copper sulphate crystals.

The action is as follows:

The sulphuric acid acts upon the zinc, forming zinc sulphate and liberating hydrogen.

$$Zn + H_2SO_4 = ZnSO_4 + H_2.$$

The hydrogen travels outwards, through the porous pot toward the positive pole. When it reaches the copper sulphate solution, it displaces the copper, which is deposited in the metallic condition on the copper cylinder, and forms sulphuric acid.

$$H_2 + CuSO_4 = Cu + H_2SO_4.$$

Thus polarisation is prevented.

Advantages.—This is a very constant cell, and can be kept working continuously for days without polarisation occurring.

Disadvantages.—1. It has only a low voltage.

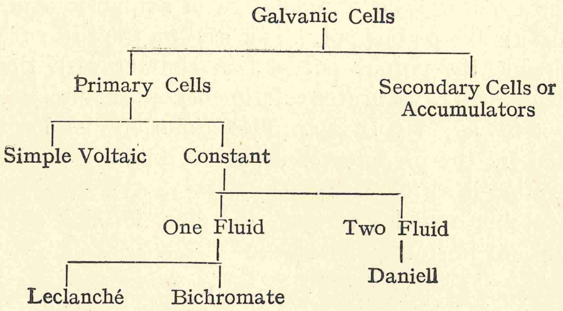
2. It does not produce a large current.

3. It is not portable, and not much used in medical work.

Accumulators or Storage Cells.—These are largely used in medical work, because they have a high voltage and are very constant.

Their construction and the chemical changes occurring in them are somewhat complicated. For a detailed description, see Appendix.

Classification of Cells



CHAPTER VII

THE RELATIONSHIP BETWEEN VOLTAGE, RESISTANCE, AND CURRENT

The cells described in the last chapter differed in three essentials:

1. In their voltage—*i.e.* the force with which they can pump a current of electricity along a given path (or circuit).

2. In the amount, or volume, of current they are able to produce.

3. In the obstruction they themselves offer to the flow of the current through them. This obstruction is called resistance. Every circuit along which a current flows has more or less resistance.

The resistance of a complete circuit is divided into two parts:

(*a*) The internal resistance, or the resistance offered by the generator of electricity itself; in the case we are considering, the parts of the individual cell.

(*b*) The external resistance, or the resistance of the whole of the rest of the circuit outside the cell.

These three factors—the force of the generator, the volume of the current, and the resistance of the circuit—are of supreme importance in the study of electricity, and every effort must be made to obtain a clear mental impression of them and their interdependence. There is a very close relationship between this important trio; in fact, they are inseparable. It is impossible to have one without the other two, for a current cannot be obtained without a generator having a certain voltage, neither can it exist without a conductor of a greater or less resistance. The volume of current flowing in any electric system will vary with the other two factors, the current being, as it were, the manifestation or result of the other two.

The variation is expressed by the following two axioms:

1. The greater the E.M.F. of any generator, the greater will be the volume of current produced.

2. The greater the resistance of the circuit, the smaller will be the resulting current. A large resistance actually reduces the volume of a current. It is possible to interpose so great a resistance in a circuit that no ordinary voltage can force a current through it.

A circuit with a very small resistance allows a large volume of current to flow through.

A simple simile may again be taken of water, pump, and pipe. The water is the current; the pump corresponds to the voltage; the pipe represents the circuit.

Now, the volume of water flowing through a water system will obviously depend on two factors:

1. The power of the pump.

2. The calibre of the pipe.

The larger and straighter the pipe, the greater will the volume of water be that flows through it.

The narrower and more tortuous the pipe, the less will be the stream: powerful pumps will be needed to force through any current. An obstruction in the pipe could be made so great that the flow was altogether blocked.

So it is with electricity.

This interdependence of voltage, current, and resistance explains why we always endeavour to reduce the resistance of a circuit to a minimum, by using good conductors wherever possible.

In considering questions of voltage, current, and resistance, it is necessary to have units of quantity for these, by means of which we can make measurements, comparisons, and records.

A Unit.—This is a definite and generally accepted constant or quantity, chosen arbitrarily of such a size as to make the most convenient measure for ordinary purposes.

The mile is a common unit of length; the hour a unit of time; the pound a unit of weight.

ELECTRICAL UNITS

These have been chosen by electricians as useful standards, and are universally accepted.

The following three are of great importance in the study of galvanism and faradism:

1. **The Unit of Electromotive Force.**—The Volt, named in honour of the celebrated physicist, Volta.

It is approximately the E.M.F. of the Daniell cell. Given this as a unit, the pumping force of other cells can be compared and measured.

For example, the E.M.F. of the Leclanché is about one and a half times as strong as that of the Daniell; its voltage is expressed as 1·5 V. The E.M.F. of the Bichromate cell is 1·8 V.; a single-celled accumulator has an E.M.F. of 2 V.

Currents from the main have their strength measured in hundreds of volts.

2. **The Unit of Resistance.**—This is called the Ohm. It may be regarded as the resistance offered by copper wire, 50 yards long and 1 sq. millimetre in cross section;

or of a column of mercury, 106·3 centimetres long and 1 sq. millimetre in cross section.

Standard coils of silver wire with a measured resistance of 1 ohm are deposited in the Board of Trade Standardising Laboratory.

With these, the resistances of other materials can be measured. The resistance of the human body with a wet skin is often quoted as being between 1,000 and 3,000 ohms; with a dry skin, 100,000 ohms; of mucous membranes, about 200 ohms.

3. **The Unit of Current.**—This is called the Ampère; it is that volume of current which an E.M.F. of 1 volt will produce in a circuit having a resistance of 1 ohm.

The total quantity of current is measured in ampère-hours—*i.e.* so many ampères flowing for so many hours.

For medical purposes the ampère would be too large a quantity for a convenient unit. We take as our unit the thousandth part of an ampère and call it the milliampère.

Ohm's Law.—Having now been provided with electrical units, we can state in terms of these how the three factors, voltage, current or ampèrage, and resistance, interact.

It was found by experiment that they were mathematically related:

1. When the resistance remained constant, doubling the voltage doubled the current; halving the voltage halved the current. This is stated scientifically as follows: "The current varies directly as the voltage."

2. If the voltage remained constant, then doubling the resistance halved the current; halving the resistance doubled the current. That is to say, "The current varies inversely as the resistance."

These two statements are combined together to form what is now known as Ohm's Law, which is stated thus:

The current measured in ampères varies directly as the electromotive force measured in volts, and inversely as the resistance measured in ohms.

Given any two of these factors, it is possible by a simple equation to find the third factor of any electrical system.

If the current is unknown, use this formula

$$C = \frac{E}{R}$$

If the voltage is unknown:

$$E = C \times R$$

If the resistance is unknown:

$$R = \frac{E}{C}$$

CHAPTER VIII

BATTERIES

A Battery.—By the term "battery" we mean two or more cells connected together in such a way as to give stronger results than one cell. For most medical purposes the strength of one cell is insufficient. Cells can be joined together in two different ways, in series and in parallel. We choose one or other of these methods according to the result we desire.

Cells joined in Series.—To join several cells in series, connect, by means of conducting wires, the negative of the first to the positive of the second, the negative of the second to the positive of the third, and so on all along the line. Finally, an unconnected zinc and an unconnected carbon are left free, forming the two poles of the combination.

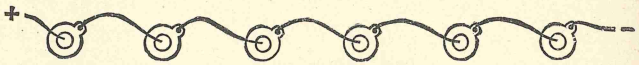


FIG. 4.—SIX CELLS ARRANGED IN SERIES.

Cells arranged in series increase the voltage of the battery in direct proportion to the number of cells connected; the resulting voltage is the sum of the voltages of the individual cells. If we connect together six cells of the Leclanché type in series, the battery will have an E.M.F. of 9 volts—*i.e.* 6 × 1·5.

When to connect Cells in Series.—Cells are connected in series when a high voltage is required to overcome a large resistance in the external circuit. Such a high resistance is always produced when the human body forms part of the external circuit; so batteries are fitted up in this way for most medical purposes. It is to be noted that although the series arrangement produces a current which flows with great force, yet the *volume* of the current is always small. This arrangement sacrifices bulk of current to the production of increased voltage. Fortunately, in treating the body, only a small current is needed, seldom more than one-tenth part of an ampère.

The question arises, Why is the volume of current reduced? The answer is, Because the internal resistance of the circuit is increased in proportion to the number of cells that the current has to make its way through, and an increased resistance reduces the current.

To sum up, the series arrangement gives a battery with a resulting voltage equal to the sum of the individual voltages of the cells, but only produces a small current.

If this is difficult to grasp, the water simile may help to give a clearer conception. Consider the circuit to be a very narrow and tortuous pipe, through which a stream of water must be driven. Much force will be required to force the water through the obstructions. A single pump may be placed upon the course of the stream; the water will be pushed along with a certain force. This may be insufficient to overcome the obstruction.

A second pump may then be placed on the course of the stream; the force will be doubled, but the quantity of water passing through the narrow pipe will be but little increased, the force of the pumps having been largely expended in overcoming the obstruction. The greater the obstruction, the greater will be the number of pumps required even to produce the smallest flow through the pipe.

Cells joined in Parallel.—In this arrangement all the negatives are joined by a common wire forming, as it were, one large negative plate. Similarly, all the positives are joined by a common wire, forming one large positive plate. The two wires form the positive and negatives poles of the battery.

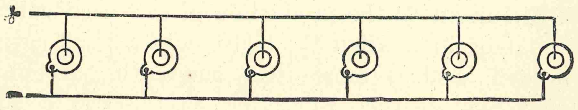


FIG. 5 —SIX CELLS ARRANGED IN PARALLEL.

Such an arrangement gives an E.M.F. equal to that of one cell only; but the internal resistance of the circuit is decreased in proportion to the number of cells, and thus the volume of current is increased.

A parallel grouping therefore produces a large volume of current, but flowing at a very low voltage.

This may seem difficult to understand, and it is necessary to go back to some first principles.

It will be remembered that the *force* which a generator of electricity gives to the current produced depends upon the potential difference between its poles, and not upon the size of its plates. Now, in a single cell, we know that the zinc pole is at a low potential, which for the sake of argument we may represent as -1. The carbon pole is at a high potential, let us say $+1$. There is a certain recognisable and unvarying potential difference between them. Now, if 20 or 200 or 2,000 zincs were all connected together, the total group would still be at the -1 potential. Similarly, the whole group of carbons, no matter how many, also still remains at the $+1$ potential. The potential difference, *i.e.* the E.M.F., is the same.

N.B.—It may here be stated that a cell of a given type, say a Leclanché, will never be able to raise its E.M.F., no matter how big it is. A cell the size of a haystack would still have exactly the same E.M.F. as a cell of the same type the size of a thimble. But the *size* of the plates has a marked effect upon the *volume* of the current the cell is capable of producing. In the first place, there are more chemicals to be consumed, therefore the lifetime of the cell will be increased. Also, there is much less internal resistance in a cell with large plates, and the volume of the current is, as Ohm's Law states, increased as the resistance is reduced.

When cells are joined in parallel, the internal resistance of the battery is in inverse proportion to the number of cells.

If two cells are present, the resistance of the battery is exactly half the resistance of one cell; if six cells are present, the total internal resistance will be one-sixth that of one cell.

For practical purposes, in medical work, the parallel arrangement is only used for heating a cautery. In this case, the external resistance is low and only a low voltage is needed; but a large volume of current is required.

The water simile may be of some help in grasping this.

We must imagine a common pipe or reservoir which we wish to fill with water; this corresponds with the circuit of low resistance. The quickest way to fill that reservoir will be to have a number of pumps, not joined one after the other, in series as it were, but each acting independently, and pouring its own stream into the common pipe.

The *force* of the flow will be small (that of one pump), but as there is no obstruction to be overcome, this does not matter, and the *volume* of the water poured into the reservoir in a given time will be great.

To sum up :

I. *A series grouping is most economical when the external resistance is large.*

Formula for calculations :

$$C = \frac{n \times \text{E.M.F.}}{(n \times r) + R}$$

Where C = current in ampères
E.M.F. = voltage of one cell
n = number of cells
r = internal resistance of one cell in ohms
R = external resistance of the circuit in ohms.

II. *A parallel grouping suggests itself when the external resistance is small.*

Formula for calculations :

$$C = \frac{\text{E.M.F.}}{\frac{r}{n} + R}$$

CHAPTER IX

THE GALVANIC MEDICAL BATTERY

THE following list gives the essential parts of the galvanic battery and its accessories as arranged for medical use :

1. A suitable wooden box fitted with a good lock.
2. Inside this a switchboard, covering the cells ; upon it are placed :
3. Terminals, to which are connected conducting cords and electrodes.
4. Cell collector.
5. Reversing switch.
6. Galvanometer.

The Terminals.—Two binding screws are always to be found on the switchboard, to which the cells are connected, as will be described under the cell collector.

One of these binding screws is marked +, indicating the positive pole of the battery ; this is also called the anode.

The other binding screw is marked —, indicating the negative pole of the battery. It is usually called the kathode.

According to the one-fluid theory, which we have so far made use of, it is assumed that the current leaves the battery by the anode, entering the patient by the electrode attached to this ; it then traverses the patient, leaving the body by the electrode attached to the kathode, and returning to the battery by the kathode.

Conducting Cords or Rheophores.—In order to convey the current from the battery, conducting cords are needed. A pair of these is supplied with every new battery by the maker.

Each cord consists of a number of strands of fine copper wire, surrounded by a layer of rubber, and finally silk covered. At each end is a metal tag, with which to attach the cord easily to the binding screws. A convenient length for the cords is about 5 feet.

Usually a pair consists of one red and one green. It is a long-standing convention that the red cord should always be attached to the anode and the green to the kathode. By doing this, one can see at a glance that the correct pole is being used in any particular condition.

The copper wire is made up of a number of fine strands in order that the cord may be very pliable. Should a cord become snapped at any point, the current will not pass through. Very often the metal part of the cord is broken, when the silk covering is intact, giving the appearance of continuity. It is very trying to have such an occurrence happen, especially if one has gone a long distance to treat a patient. It should therefore be made an inviolable rule that an extra pair of cords should always be at hand, in case the pair in use should unexpectedly be found defective.

A good pair of cords costs about 2*s*. 3*d*. Excellent cords, cased entirely in rubber tubing, and therefore completely insulated, can also be obtained at 6*s*. 6*d*. a pair.

Electrodes.—The term "electrode" signifies a pliable surface of good conducting material which can be well adapted to the part of the body receiving treatment, and through which the current is conveyed from cord to patient.

Electrodes are made of every kind and shape.

Large, flat pieces of lead, tin, zinc, or aluminium, fitted with binding screws, make very satisfactory electrodes.

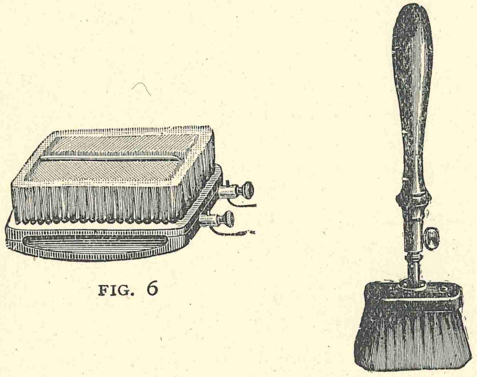


FIG. 6

FIG. 7.

BRUSH ELECTRODES.

Others are composed of a piece of chain mail, the links being usually of zinc or copper. These are very pliable.

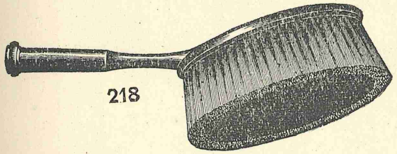


FIG. 8.—BRUSH ELECTRODE

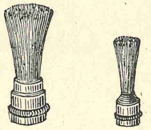


FIG. 9.—METAL BRUSH ELECTRODES.

Metal gauze or tinsel, such as is used for fancy dresses, can be adapted for the purpose. It is light, pliable, and can easily be cut to any shape required.

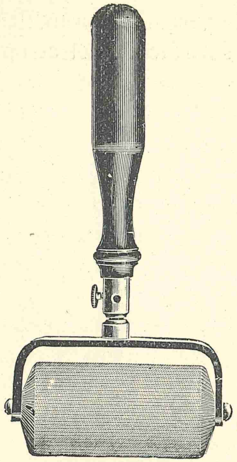


FIG. 10.—ROLLER ELECTRODE.

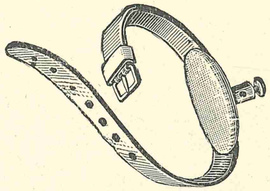


FIG. 11.—WRISTLET ELECTRODE.

Small metal plates, mounted on wooden handles, and filled with binding screws, serve certain purposes.

Brushes, rollers, wristlets, and sponges all have their uses.

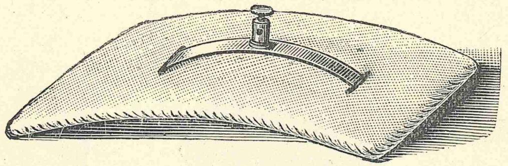


FIG. 12.—PLATE ELECTRODE.

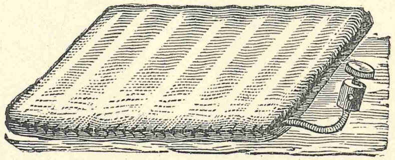


FIG. 13.—PLATE ELECTRODE.

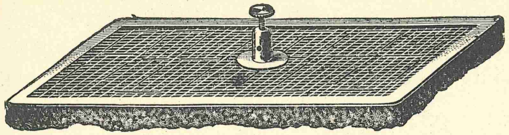


FIG. 14.—FLEXIBLE GAUZE AND SPONGE ELECTRODE.

There are rods for entering cavities, and needles for destroying hair follicles; douche electrodes for internal use and cup electrodes for ionisation. In fact, there are almost as many different kinds of electrodes as there are people using the galvanic battery.

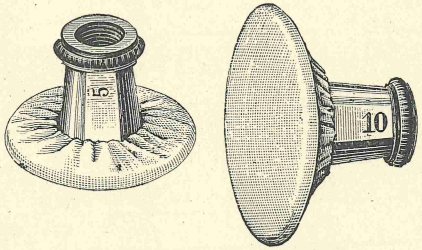


FIG. 15.—DISC ELECTRODES.

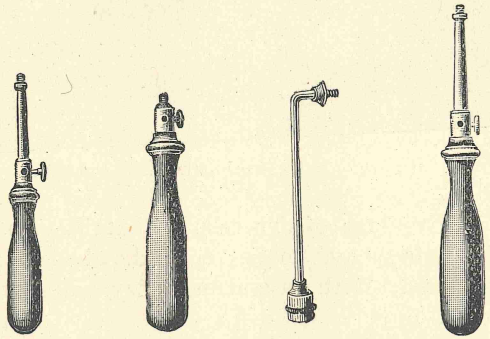


FIG. 16.—ELECTRODE HANDLES.

The Cells of the Galvanic Battery.—Cells of the Leclanché type are most commonly used. Where portability has to be considered, dry cells are preferable. The chief disadvantage of dry cells is that they cannot be recharged, but have to be replaced, when exhausted, by new ones. With careful use, they will last one or two years.

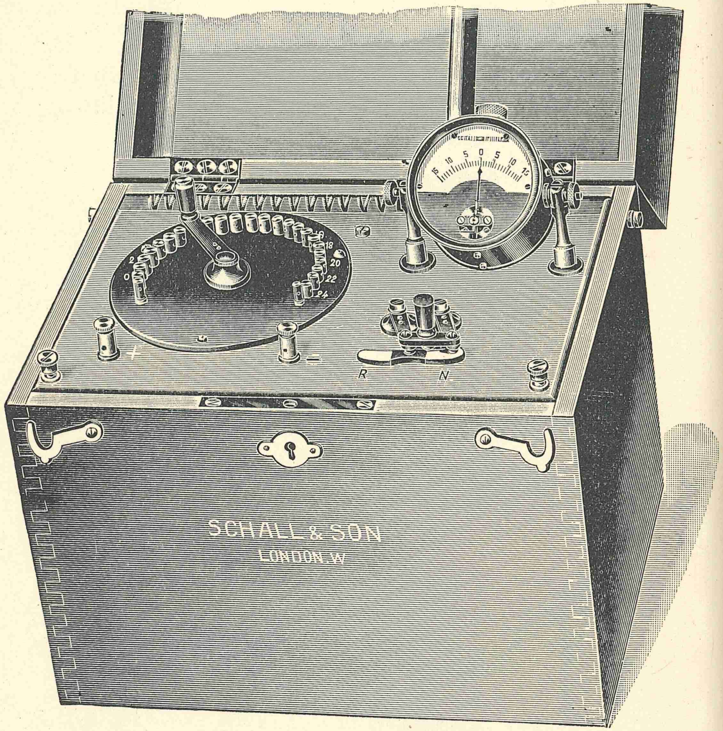


FIG. 17.—GALVANIC MEDICAL BATTERY.

For most medical purposes a battery of from 24 to 36 cells is desirable. These are connected in series, giving an E.M.F. of about 1·5 volts per cell.

It occasionally happens that one or more cells from careless use and short circuiting may become exhausted before the rest. If this occurs, the dead cell must be removed and replaced at once. The reason for this is that a dead cell in the circuit greatly increases the resistance and throws more strain on the remaining cells. Its presence also causes shocks of an unpleasant nature to the patient. A dead cell can be detected by the galvanometer; the needle registers quite steadily while the good cells are in use; when the dead cell is reached, it suddenly swings back to zero.

Cell Collectors

By means of the current collector, or cell collector, the number of cells in use can be regulated and the current increased or decreased according to need. There are two kinds:

1. Single cell collectors.
2. Double cell collectors.

I. **Single Cell Collector.**—This consists of a circular vulcanite base upon which are arranged a number of metal pegs in such a manner that a crank can be brought into contact with each in turn. The cells beneath the switchboard are connected with these pegs and with the terminals of the battery as follows:

1. A wire leads direct from the first zinc to the negative terminal.
2. A wire leads from each carbon to each peg, except the first, to which no cell is connected.
3. A wire connects the crank to the positive terminal of the battery.

When the crank rests upon peg 0, no cells are connected; there is no complete circuit.

When the crank is moved on to the following pegs, the corresponding cells are brought into use.

In the diagram, the current, beginning at the zinc of cell 1, passes through cells 2, 3, and 4, thence through the crank to the anode; it traverses the patient and returns to cell 1, again via the kathode.

It is very important to see that the crank passes slowly and smoothly from peg to peg in turning on the current. These pegs are placed close together in order that the crank should not completely leave one until it is in contact with the next, so preventing a break of the current at any point.

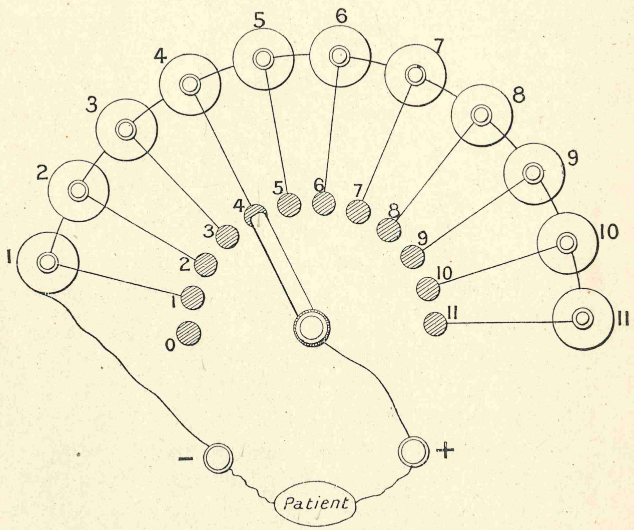


FIG. 18.—PLAN OF SINGLE CELL COLLECTOR.

Short Circuiting in the Cell Collector.—It is also very important never to allow the crank to remain for any length of time in contact with two pegs. If this is allowed, a short circuit is formed, and the bulk of the current passes from peg to peg and so back to the battery, instead of travelling the long circuit through the patient.

Short circuiting will be prevented if due care is taken to feel the slight jerk produced every time the spring of the crank slips into a small socket on the vulcanite placed there for it.

With the single cell collector, it will be seen that the first cells are always in use, whether a large or small current is needed. This results in unequal wear of the cells. In order to obviate this, a double cell collector has been devised which enables one to select and use any group of cells independently of the others.

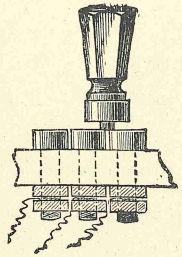


FIG. 19.—CRANK INCORRECTLY PLACED.

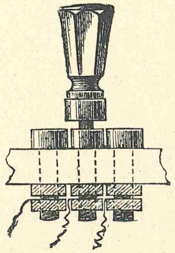


FIG. 20.—CRANK CORRECTLY PLACED.

II. **The Double Cell Collector.**—Two cranks, placed on the same axis, but insulated from one another, are used. One is connected with the negative terminal and one with the positive terminal of the battery. The zinc of the first cell is connected with peg 1; the positives are connected as usual with the rest of the pegs.

By moving both cranks any batch of cells can be selected, those between the cranks being used.

In order to begin the treatment, both cranks should

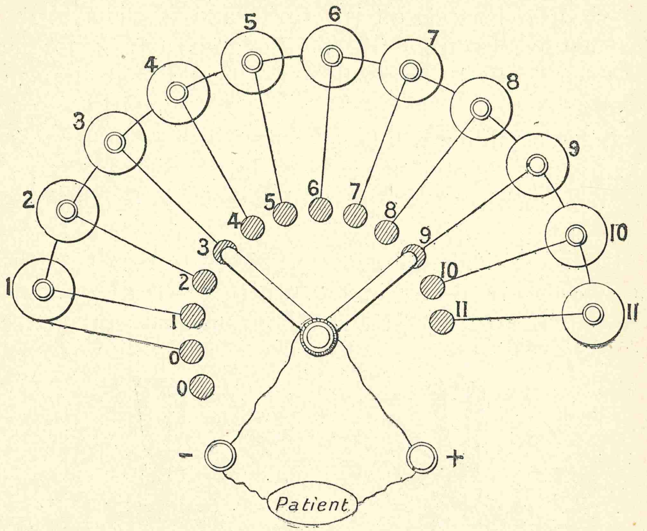


FIG. 21.—PLAN OF DOUBLE CELL COLLECTOR, CELLS 4–9 IN USE.

be placed side by side, when only one cell will be in use. The cranks can be turned round the dial together until the batch of cells to be used is reached. Then, while one crank remains stationary, the other can be slowly moved

from peg to peg until the requisite number of cells are connected.

The double cell collector is especially useful for batteries which contain a large number of cells and which are liable to irregular use.

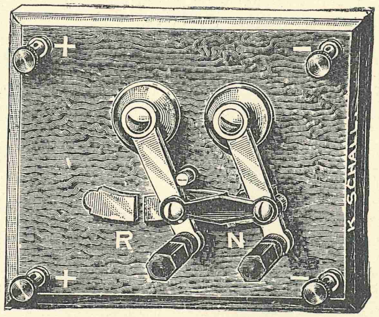
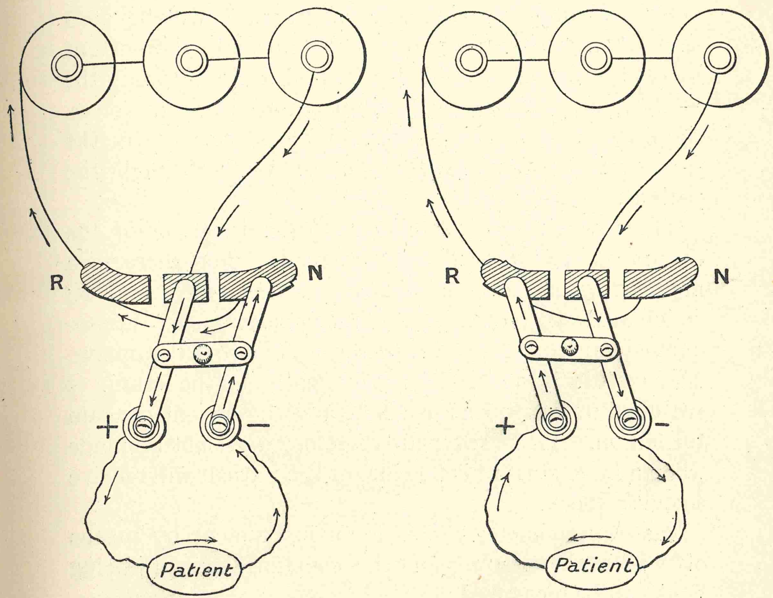


FIG. 22.—THE CURRENT REVERSER



CURRENT REVERSER AT NORMAL.

CURRENT REVERSED.

FIG. 23.

The Current Reverser.—The current reverser is a switch connected with an ingenious arrangement of wires by means of which the direction of the current in the external circuit, *i.e.* through the patient, can be reversed when necessary.

It is to be clearly understood that the current *always* runs in the same direction in the battery, from the positive pole, through the external circuit, and back to the negative pole. The current reverser is merely a mechanical device by means of which the current can be made to leave the battery by the terminal marked — and re-enter it by that marked +.

By carefully studying the diagram, it will be seen that when the switch points to N (normal), the current leaves the battery by the + terminal and returns by the — terminal. When the switch stands at R (reverse), the current leaves by — terminal, and returns by the + terminal, thus changing the direction through the patient.

The reversing switch also causes a breaking of the circuit as it is moved from N to R. For there is a moment when both cranks are resting on N and R, which are both in contact with the negative pole. Consequently at this moment there is no current running. The circuit is suddenly made again as the crank is switched over as far as it will go and the current is again turned on. These reversals therefore must not be made when a large current is flowing, or the patient will receive a severe shock.

The Galvanometer.—This is an instrument by means of which the amount of the constant current being used can be measured.

When very large currents are used, it is graduated in ampères, and is then called an ampère meter or ammeter.

For medical purposes it is graduated in milliampères, and is frequently called a milliampère meter.

The principle upon which the galvanometer is constructed is based upon Faraday's observations concerning induction.

We have already seen, when considering Oersted's experiment, how a wire carrying an electric current has

the power to deflect a compass needle from its north and south position.

The extent of the deflection depends upon the strength of the current in the wire. In this way, a graduated scale can be made, so that the movement of the needle along this will indicate the amount of the current which causes the deflection. A simple type of galvanometer, made on these lines, was in use before the improved type, now known as the D'Arsonval or moving coil instrument, was invented.

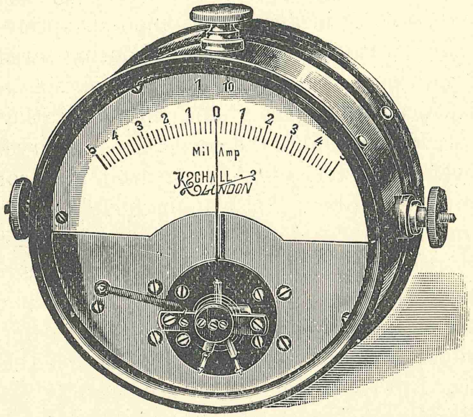


FIG. 24.—THE D'ARSONVAL MILLIAMPÈRE METER.

The drawbacks of the old type were twofold: 1st, it would only work in the horizontal position; 2nd, it was much influenced by the presence of magnets or currents from the main.

In the improved, or moving coil, instrument the magnetic needle is replaced by a slender coil of wire suspended in relation to a fixed magnet. Such a coil carrying a current is called a solenoid. When no current is passing through the coil, it is quite stationary, and a needle or indicator attached to it points to zero on the scale.

When a current enters the galvanometer, it is led through this coil. Magnet and coil now interact upon each other. The magnet is fixed, but the coil is freely movable. It tends to set itself at right angles to the magnetic lines of force. The stronger the current, the greater will be the movement of the coil and of the indicating needle. When the current ceases, the coil is brought back to its initial position by means of two fine hair springs.

Such an instrument is capable of acting satisfactorily in any position; it is not affected by outside magnetic and electrical influences; and the indicating needle moves steadily without the oscillations observed in the older type of meter. For this reason it is sometimes called the " dead-beat " galvanometer.

The mechanism is very delicate; the fine hair springs are very readily strained if too strong currents are used. Care must therefore be taken never to use a stronger current than the galvanometer is made to register. Such an overdose of current may be produced if the electrodes are allowed to touch each other accidentally.

The Graduation of the Galvanometer.—Many instruments are graduated to register a total current of 5 m.a., but their working range can be increased by one or more shunt circuits.

In the diagram the fine wire carries all the current which causes a deflection of the indicator. Let it be assumed that 5 m.a. is the limit, as marked on the scale.

If one wishes to use a stronger current, a large proportion (and a known proportion) must be "shunted" on to another path, which will not influence the indicator. This is shown in the diagram as a wire marked 10. This is the first shunt circuit, and it can be closed by turning the screw shown at the side.

The current entering the galvanometer now has two paths before it; it will divide itself accurately between them according to their relative resistances. If the fine coil has a resistance of nine-tenths and the shunt wire one-tenth of the total resistance, then one-tenth of the total current only will pass through the fine coil, and nine-tenths will pass through the shunt.

When the shunt is in use, then we know that only one-tenth of the total current is passing through the indicating coil, and that the current is really ten times as strong as the needle indicates.

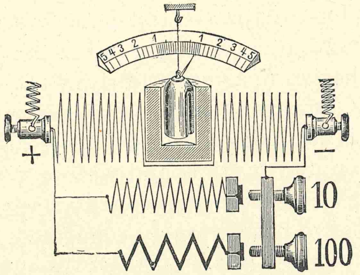


FIG. 25.—DIAGRAM SHOWING TWO SHUNT CIRCUITS OF GALVANOMETER.

Thus, as in the diagram, if it points to 1 m.a., we know that the real strength is 10 m.a. If the needle points to 5 m.a., the total current flowing is really 50 m.a.

In the diagram a second shunt is shown, which is capable of taking $\frac{99}{100}$ of the total current, because its resistance is only $\frac{1}{100}$ of the total resistance.

The screw which brings the shunt into the circuit automatically registers a number in a small window on the dial face. This figure indicates the total strength of the current that the instrument is capable of registering at that time.

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CHAPTER X

DIFFERENT EFFECTS OF ANODE AND KATHODE

VERY different effects are produced by anode and kathode, both on the tissues of the patient and on any solutions through which the current may be led.

It is therefore of the greatest importance to be quite certain which terminal is anode and which kathode.

Usually the terminals are clearly marked + and –. Occasionally, however, batteries are met with in which the polarity is not indicated, or in which the marks have become obliterated by time and wear. When batteries are re-charged, it may occasionally happen that the wires inside have been wrongly connected.

On apparatus which is used from the main by means of a wall plug, the terminals are frequently not marked, as the direction of the current varies according to the way in which the adaptor is fitted into the socket. In all these cases it is essential that we should have an easily applied method for determining the polarity.

TESTS FOR POLARITY

I. **Pole-testing Paper.**—This can be bought in small books from the electrician. It consists of white absorbent paper impregnated with a certain chemical called phenol phthalein; this is ordinarily colourless. When brought into contact with an alkali, it turns a brilliant red.

Now, alkalis are produced at the kathode when a constant current is passed through tap water.

In order to apply the test, take a strip of the pole-finding paper, soak it in water and lay it upon a wet pad of cotton or other conducting surface. Place the two ends of the conducting cords upon the strip, but a little distance apart.

Notice that the reversing switch is turned to N, and then switch on the current, which must be carefully regulated if the galvanometer is in the circuit.

After a minute or so the paper beneath one wire is stained a vivid red. This is therefore the kathode. No change occurs at the anode.

II. **Litmus Paper.**—If pole-finding paper is not available, the test can be equally well applied with litmus paper, which is to be found in every hospital ward and doctor's consulting-room.

Litmus is a chemical reagent which becomes red with acids and blue with alkalis. It can be bought in small books of either a red or blue colour.

To make the test, the strip of litmus paper is moistened and laid upon a wet surface, as in the first experiment. The current is then led through it.

If blue litmus is being used, a reddening occurs at the anode, where acids are produced. If red litmus is being used, it becomes blue round the kathode, where alkalis are produced.

III. **Electrolysis.**—If neither litmus nor pole-testing paper is available, there is a very simple test which can easily be applied at any time. It depends upon the fact that the constant current splits up water and salts dissolved in water into their simple constituents. This splitting up of substances into their elements by the constant current is called electrolysis.

To perform the test, take a basin of hot water and place the two electrodes in it, taking care that they do not touch each other.

The current is slowly turned on, after observing that the reversing switch is at normal.

In a short time one electrode will be covered thickly with bubbles of gas. This is hydrogen, which is freed at the kathode.

If the experiment is continued for a considerable length of time, the other electrode will also show some bubbles on it, but never to the same extent as the kathode.

The water has been split up by the current into its two constituents hydrogen and oxygen, in the proportion of two volumes of hydrogen to one of oxygen:

$$H_2O = H_2 + O.$$

Therefore the hydrogen always appears in larger quantities round the kathode than the oxygen round the anode.

Students often confuse themselves at this juncture. They remember that in the simple voltaic cell the hydrogen collects as a layer of bubbles on the positive plate. This difference must be thought out carefully.

In the first instance, the electrolysis is occurring *in* the cell itself; in the second instance, it is only occurring in a solution which is placed in the circuit and which has no connection with the production of the electricity.

In the cell, the current travels through the liquid electrolyte from the negative *plate* to the positive *plate*, and the bubbles of hydrogen go with it to the positive plate.

In the solution on the outside circuit, the current travels from the anode or positive *pole* to the kathode or negative *pole*, and the bubbles go with it to the negative pole.

Effects produced by Anode and Kathode on Patient.—The effects produced by the constant current on the patient may be considered under two headings:

1. Physiological.
2. Chemical.

I. **Physiological Effects.**—These are the result of what is known as electrotonus.

When a constant current is passed through a nerve and muscle, changes occur in the irritability of the nerve and muscle. By irritability we mean the power of response to a stimulus. The irritability is altered as follows:

1. In the region of the anode there is a decrease of irritability resulting in less readily obtained muscular contractions and in the decrease of sensation and deadening of pain.

This condition of decreased irritability is called *Anelectrotonus*.

2. In the region of the kathode there is a condition of increased nervous irritability resulting in more readily obtained muscular contractions and in greater stimulation of nerve terminals. Thus, sensation is increased, and vasomotor effects produced resulting in hyperæmia and reddening of the part. This condition of increased irritability is known as *Katelectrotonus*.

II. **Chemical Effects.**—The body must be regarded as a sac containing fluids which hold various salts in solution. Let us assume that the chief of these is sodium chloride.

We have already seen that the constant current splits up salts into their constituents, and that the metallic portion is attracted to the kathode, the acid portion to the anode.

This also occurs in the tissues of the body. This redistribution is of value in the increase of tissue changes which are summed up in the word Metabolism.

Fatigue products, such as carbonic acid and sarcolactic acid which result from excessive muscular activity, are sent on their way out of the muscles toward the poles and so more readily got rid of. This constitutes what is known as the "refreshing" action of the current.

Besides these chemical effects, the constant current is of the greatest value in connection with ionic medication—*i.e.* in the introduction of drugs locally into the tissues.

Since we now realise that the anode always attracts acids and repels metals, it will be understood that if we wish to introduce a metal into the tissues we must use the anode. Also, if we wish to withdraw acids from the tissues we must use the anode.

This has been beautifully demonstrated in the case of a gouty subject. A gouty joint is overloaded with uric acid. If it be placed in a bath of water with the + pole, the uric acid is attracted out of the tissues into the water on its way to the anode. Chemical tests have been applied in such cases, and the acid found to be present in the water.

To sum up:

1. The anode produces—

(*a*) A condition of anelectrotonus. It is therefore soothing to pain and is used for conditions such as neuralgia and neuritis.

(*b*) A drying effect upon the tissues, due to the formation in its neighbourhood of acids which harden and dehydrate.

(*c*) A depleting effect upon the circulation, and is used in cases of inflammatory œdema.

(*d*) The introduction of metals into the tissues in ionic medication.

2. The kathode produces—

(*a*) A condition of katelectrotonus in its neighbourhood and is used in cases of paralysis and paresis.

(*b*) Vaso-dilatation and congestion. Because of the increased flow of the circulation it increases the absorption of exudations.

(*c*) A moistening effect in its neighbourhood, partly the result of the increased vascularity.

(*d*) The introduction of acids into the tissues, and is so used in ionic medication.

CHAPTER XI

HOW TO USE THE GALVANIC BATTERY

I. Before the treatment is begun:

(*a*) All switches must be examined.

The crank of the cell collector must be at *O*.

The reversing switch must stand at *N*.

The galvanometer screw must be turned so that the instrument is adjusted to register the amount of current likely to be used.

(*b*) It is necessary to examine the conducting cords in order to see that they are intact and that their metal tags are bright and clean. Rust and verdigris interfere with the flow of the current. It is customary to insert the red cord into the positive and the green into the negative terminal. The binding screws must be screwed up tightly.

(*c*) Electrodes suitable as regards shape, size, and pliability must be chosen, and firmly connected to the conducting cords.

(*d*) If the battery has not been used for some time, the operator should carefully test the current upon himself in order to see that everything is in perfect working condition. The current should increase gradually and almost imperceptibly without any unpleasant jerks. If shocks are produced, there is probably a loose connection in some part of the circuit. Every binding screw and junction must be carefully examined, and

any loose contacts tightened up. The studs of the cell collector may be dirty, any verdigris and rust upon these making contact very uneven. These should be kept very bright and smooth with *fine* emery paper.

Loose connections inside the battery may also be present; anybody familiar with the construction of the battery can safely lift the switchboard and examine the wires and binding screws of the cells.

Sometimes a dead cell is present among a number of fairly strong ones. The presence of a dead cell is indicated by the galvanometer. When the crank reaches the corresponding stud, the needle swings back to zero and the patient receives a severe shock. A battery should never be used for treatments if a dead cell is present because of painfulness of the shocks produced, and also because its presence greatly increases the resistance of the internal circuit and so throws more strain on the other cells.

Whenever a dead cell is detected, the battery should be sent to the instrument maker to have the defect remedied. If time is of great consequence and if the operator is thoroughly familiar with battery construction, he may remove the dead cell and replace it temporarily by the last cell of the series.

II. **Preparation of the Patient.**—(*a*) The patient must be arranged in a comfortable and suitable position with the parts to be treated well supported, and the clothes protected with towels and mackintoshes.

(*b*) The skin must be very carefully examined for abrasions, etc., as the current should not be used where there are skin lesions. Wherever the epidermis is defective the resistance is lowered, and the current would therefore concentrate at such areas, possibly resulting in a serious electrolytic burn.

If possible an area should be chosen for the application of the current where the skin is normal. If this is impossible, the abrasions must be protected from the effect of the current by covering them with collodion, new-skin or adhesive rubber plaster.

(*c*) The part to be treated must be thoroughly moistened with hot water to which some substance which will increase conductivity has been added. A little salt or vinegar may be used.

If the skin is very greasy it must be washed over with spirit soap or ether. This is important, as a dry or greasy skin increases the resistance.

(*d*) Large, thick pads well soaked in *hot* water must be placed between the skin and the metal part of the electrode. The padding may be of lint, gamgee tissue, cotton wool, linen, cotton or towelling. The essentials are that it should be clean, soft, smooth and absorbent, and equal in thickness to at least sixteen layers of lint. In applying the padding the greatest care must be taken that it lies absolutely flat and free from creases upon the skin surfaces. Burns frequently form at the situation of a crease, because here the pressure is greater than elsewhere and the current concentrates at points of pressure. It is also important that the pad extend well beyond the metal edge of the electrode on every side. Where a limb is to be treated, the pad may very conveniently encircle the whole part. This does away with the danger of a free edge where the pressure and contact may be uneven.

Pads and electrodes must be kept in firm position with equal contact throughout the treatment. In the majority of cases equality of pressure is best obtained by fixing with a well-applied bandage.

When applied to parts such as the sternum or face, the electrode may be held in position. When applied to the back, the patient may lie upon it.

In some places the electrode may be most satisfactorily fixed by means of a waterproof-covered sandbag.

(*e*) Special care must be taken that the metal part of the conducting cord does not come into contact with the patient's skin at any place. Carelessness in this respect has frequently resulted in very serious burns.

(*f*) Short circuiting must be avoided. This occurs if the two electrodes are placed close enough together to touch each other; or if the skin between the two is very wet. In both these cases the current would choose to run direct from electrode to electrode instead of penetrating the tissues of the patient, because currents always pass where the resistance is least.

(*g*) The electrodes must not come in contact with any jewellery that the patient may be wearing. The metal, acting as a good conductor, would cause all the current to concentrate at this place, so possibly producing a burn.

III. **The Treatment.**—(*a*) When both electrodes have been correctly applied, the patient must be covered lightly and kept warm during the treatment. It is very important that the part treated should be thoroughly supported and relaxed.

The current must be turned on *very* slowly and gradually, the crank handle being moved evenly and smoothly from peg to peg and care being taken to avoid short circuiting.

The patient soon becomes conscious of a sharp pricking sensation and a feeling of heat. At first this seems rather severe, but the patient gradually becomes accustomed to it and its intensity diminishes. The current can then be slightly increased. It is surprising how large a current can be comfortably taken, provided it be very gradually and slowly increased.

(*b*) During the treatment the padding must be kept moist. The patient complains of much discomfort and burning over the whole area if it begins to get dry; also, the current will be decreased, as shown by the galvanometer, because the resistance is greater when the pads become dry. If drying occurs, the padding must be removed and wetted; notice especially that the current must be slowly turned off before the pad and electrode are removed. The kathode is the electrode at which burns are most likely to occur, therefore this should be especially watched and attended to.

(*c*) The patient should be instructed to mention any unusual sensation, and especially any local burning or pain, and the patient's complaints must never be disregarded. The current must be turned off, the electrode removed and the part examined. Many a serious burn will be avoided if this rule is kept. Unfortunately, burns are sometimes produced without the patient being aware of the fact.

Burning may be caused by some metal having come in contact with the skin, by drying of the pads, or by creases and unequal pressure of the pads. It may also be due to the use of too small pads.

It is often said that for every milliampère of current to be used, one square inch of electrode should be allowed.

IV. **Termination of Treatment.**—(*a*) The current must be turned off just as slowly and carefully as it was applied. A rapid reduction of the current is most painful to the patient.

(*b*) The electrodes must not be removed until the current is completely turned off.

(*c*) The skin must be at once carefully dried and examined for undue redness, blisters, or burns. Marked irritation should be allayed by the application of a soothing ointment such as hazeline cream. Electrolytic burns must be covered very carefully with an antiseptic dressing and treated with all the precautions observed for any wound. Such burns are considered in detail in a later chapter.

V. **The Care of the Battery.**—(*a*) All switches must be turned off at the end of the treatment.

(*b*) The switchboard and its various metallic parts must be carefully cleaned and dried.

(*c*) Pads should be rinsed out and kept in an antiseptic solution or dried if they are to be used again.

(*d*) Cords and electrodes must be carefully dried before being put away. Otherwise the cords become eroded and soon break, and the binding screws of the electrodes get rusty and ill-fitting.

Wet objects must never be put away in the battery box.

(*e*) From time to time the metal binding screws and pegs of the battery should be carefully polished with fine emery paper.

Any collection of verdigris between the pegs must be completely removed.

Cleanliness is of the greatest importance in maintaining the usefulness of the battery. Very many of the minor troubles to which a battery gives rise are caused by failure in this respect.

(*f*) All electro-medical apparatus should be carefully handled. The battery should not be moved about more than necessary. Jarring is detrimental to the galvanometer, which is very delicately constructed and easily put out of gear.

CHAPTER XII

THE USES OF GALVANISM

THESE may be divided into two large groups:—

1. Therapeutic uses.
2. Diagnostic purposes.

Therapeutic uses will be considered here, but the question of muscle and nerve testing will be deferred to a later chapter.

Methods of Application.—Galvanism may be either bipolar or unipolar, stabile or labile, according to the arrangement of the electrodes.

1. **Bipolar Galvanism.**—When both anode and kathode are placed upon the affected part and both are of value in the treatment of the diseased condition, the method is called bipolar.

2. **Unipolar Galvanism.**—If only one pole is of value in the treatment of the condition, and the other pole is possibly detrimental, then the useful pole is placed upon the part affected and is called the *active* electrode. The other pole must be placed upon some distal part of the body; its use is merely to complete the circuit, and it is spoken of as the *indifferent* electrode. Galvanism, so applied, is described as unipolar.

3. **Stabile Galvanism.**—Stabile signifies stationary, and is the term applied to the method in which both electrodes are fixed upon the patient and kept at rest throughout the treatment. The current in this case remains constant or continuous.

4. **Labile Galvanism.**—Labile signifies movable or variable. Labile galvanism is applied by moving the active electrode up and down, or on and off the part treated. The active electrode in this case is usually a roller, disc, or sponge. By this means the current is being repeatedly made and broken or varied in intensity.

Galvanism, either stabile or labile, unipolar or bipolar, is used in the treatment of a great many different conditions.

The constant current, either applied to the whole body or merely locally, exerts its main effect upon the general metabolism. Thus, the nutrition of the tissues is improved; the healing of various lesions is hastened; the nerves are improved in tone; pains and achings due to lowered vitality are dispelled. It is to be noticed that all these effects are produced without any muscular contractions. The constant current does not cause muscular contractions unless it is suddenly made or broken.

Uses.—1. The constant current, because of its beneficial effect upon *metabolism*, is used for the following conditions, when it may be applied to the whole body as a hydro-electric bath, or especially to the nervous system as described under Central Galvanism:—

(*a*) Insomnia.
(*b*) Neurasthenia.
(*c*) General debility.
(*d*) Hysteria.
(*e*) Rickets.
(*f*) Anæmia.
(*g*) Other constitutional diseases.

2. For various painful conditions stabile anodal galvanism is used, because of the condition of anelectrotonus produced:

(*a*) Acute neuritis, as sciatica and lumbago.
(*b*) Various neuralgias, especially of the face.
(*c*) Headaches of different kinds.
(*d*) Acute inflammations, such as recent sprains.

3. For spasmodic conditions, in which the anelectrotonus produced in the region of the anode tends to reduce the irritability.

Anodal stabile galvanism is therefore used for:

(*a*) Spasmodic wryneck.
(*b*) Habit spasms.
(*c*) Writer's cramp.
(*d*) Spastic paralysis.

4. For certain vaso-motor affections, galvanic reversals are useful, metabolism being improved and the circulation hastened. This is especially indicated for:

(*a*) Chilblains.
(*b*) Frost-bite.
(*c*) Raynaud's disease.
(*d*) Volckmann's ischæmic contracture.

5. For the introduction of drugs into the tissues in ionic medication, the active electrode being chosen according to the nature of the drug used.

6. Where electrolytic changes in the tissues are required:

(*a*) Removal of hairs.
(*b*) Warts.
(*c*) Nævi.

7. In cases of muscular weakness, wasting, or paralysis, galvanism is very useful if some means are

employed for interrupting the current or varying its strength. See in detail, Chapter XVII.

General Galvanism.—This is used for the metabolic changes it evokes in various constitutional troubles, especially neurasthenia and insomnia.

The most convenient method of application is by means of the full hydro-electric bath; this requires a considerable amount of special electrical apparatus which makes its use impracticable in many instances.

In its place the galvanic battery may be used, the whole of the body being treated, area by area, with the constant current. A large indifferent electrode is placed beneath some portion of the spine, and a sponge electrode, usually attached to the anode, is moved over the various parts of the body, using a current just strong enough to be pleasant.

Central Galvanism.—In this particular type of galvanism, only the nervous system is treated. It is used for its soothing effect in cases of insomnia, and in neurasthenia where the patient is irritable and restless.

Requirements.—The galvanic battery.

A large flat metal electrode supplied with a large pad.

A sponge.

Towels and mackintoshes.

The patient is to be comfortably seated in such a position that the whole spine is exposed. If for any reason the sitting position cannot be adopted, the patient may lie either on the face or on one side.

The hair must be quite devoid of all metal hairpins or clasps, as the head receives part of the treatment.

The large flat electrode is attached to the kathode. When the pad has been well soaked in hot saline solution (1 teaspoonful of salt to a pint of water), it is applied just over the solar plexus, covered by the electrode, and protected from the clothing by a towel and mackintosh. The patient can very conveniently hold it in position during the treatment.

The active electrode, the anode, is composed of a small sponge in which the metal end of the conducting cord is completely embedded. It is to be well soaked, and then held firmly in position, first on the patient's forehead and then on the vertex. The hair must be damp in order to allow the current to pass. If it is greasy, the resistance is greatly increased; the grease can be removed by means of a little spirit soap.

When the sponge is pressed firmly in position, the current is very gradually turned on, until the patient becomes conscious of it. The usual sensation is that of a somewhat unpleasant metallic taste in the mouth.

The current is kept constant at about 3 m.a. for about three minutes. It is then to be slowly turned off before removing the sponge.

The back and sides of the neck are next treated. The sponge is held immediately to one side of the cervical spine, and the current gradually brought up to 5 m.a. The sponge is then moved firmly and slowly up and down the sides of the neck, in both posterior and anterior triangles, in order to affect the spinal nerves, the vagus and the phrenic.

About three to five minutes is given to each side.

The whole length of the spine is finally treated by bringing the sponge gradually down to the dorsal region; it is to be held steady for a moment, while the current is gradually increased up to about 10 m.a. When this is reached, the sponge is then moved slowly up and down each side of the spinous processes, but not immediately over the bony prominences. The back is treated for about ten minutes.

Terminate the treatment by gradually turning off the current before removing either electrode.

CHAPTER XIII

IONIC MEDICATION

THIS is a treatment which has had a great vogue during recent years. It was first made use of in the treatment of disease by Professor Leduc of Nantes in 1900. The idea had previously been suggested by Edison as long ago as 1890.

Stated briefly, the treatment consists of the introduction directly into affected tissues of curative drugs by the action of the galvanic current.

There are certain drugs which have long been recognised as especially useful for certain diseases, as salicylates for rheumatic affections, lithium for gout, and zinc solutions for septic conditions. Hitherto these have been administered by the mouth or applied to the surface to be slowly absorbed.

Professor Leduc showed experimentally that a great many of these useful remedies could be driven rapidly and deeply into the actual tissue cells at the spot where they were most needed by means of the constant current.

The kind of substances which can be used in this way is limited to three chemical groups, acids, bases, and salts. These substances, when dissolved in water, split up into simple groups of atoms called ions. It is by means of their movements through the fluid that the electric current is conducted. Such substances which split up into ions and then conduct electricity are called electrolytes.

The following is a list of the substances most commonly used in ionic medication:

1. *Applied under the kathode*— negative

    Various preparations of iodine.
    Sodium chloride (common salt).
    Sodium salicylate.

2. *Applied under the anode*— Positive

    Lithium salts.
    Zinc salts.
    Copper salts.
    Magnesium salts.
    Cocaine.
    Morphine.
    Quinine.
    Aconite.

Method of Application.—All the ordinary arrangements and precautions (already detailed in a previous chapter) for the application of the constant current are to be observed. The only way in which ionic medication differs from stabile galvanism is that the padding and covering of the active electrode is to be well soaked in a hot 1 per cent. solution of the required drug. Strong currents and long treatments are indicated, because the amount of the drug driven in is in direct proportion to the strength of current and the length of time it is running.

All solutions used must be hot; hot water being more comfortable for the patient and a better conductor of the current.

Demonstration of the Different Effects of the Poles.—It is of prime importance that the drug to be used is placed in conjunction with its proper pole. If used with the wrong one, no harm is caused; the drug merely does not enter the tissues and that particular treatment is wasted.

In order to demonstrate the fact that anode and kathode have different effects upon the above-mentioned drugs the following experiments may be made.

1. Paint a small quantity of tincture of iodine in two different patches on a limb. The brown stain is to be made sufficiently clear and definite.

Over each patch place a large moist pad and to one apply the anode, to the other the kathode. Pass a few m.a. 10 or 15 for about ten miuntes. According to rule, the kathode only should have driven the iodine into the tissues. If the experiment has been quite successful, this fact will be clearly obvious, for all the brown stain will have disappeared from beneath the kathode, whereas it will be still visible under the anode, if not on the skin, at all events on the pad.

2. A somewhat similar experiment may be made with cocaine hydrochloride. This is introduced only with the anode. If used under both poles, the skin under the anode, into which the cocaine has been driven, will be anæsthetic, whereas the skin under the kathode will remain unaffected, because the cocaine has merely stayed on the pad.

3. Take a piece of glass tubing and fill it with wet cotton wool. At one end place in a small plug of wool which has been soaked in potassium iodide solution; at the other end a plug soaked in starch solution. Insert the kathode into the potassium iodide end, the anode into the starch end, and pass the current.

The constant current will dissociate the potassium iodide into its elements, potassium and iodine, and will carry the iodine from the kathode to the anode, where it will show itself by turning the starch blue.

THERAPEUTIC USES OF COMMON IONS

I. **Salicyl Ions.**—Introduced by means of the kathode in the following affections:

1. Chronic joint rheumatism.
2. Chronic myositis and fibrositis.
3. Chronic rheumatic bursitis.
4. Rheumatic neuritis, as lumbago, sciatica, brachial and trigeminal neuritis.
5. For the chronic pain and aching so often left after injuries to joints and ligaments, as sprains, fractures involving joints, dislocations.
6. Rheumatoid arthritis.
7. Gouty arthritis, in combination with lithium under the anode.
8. Facial paralysis of rheumatic origin.
9. Acne.

In all the above treatments, all grease must be removed, as greasy material offers an impediment to the passage of salicyl ions into the tissues.

II. **Iodine Ions.**—These can be introduced by the kathode from any of the soluble preparations of iodine. Those in common use are:

1. **The Tincture of Iodine.**—This is a 2½ per cent. solution of iodine in alcohol. It is frequently used in full strength, the skin being painted with the solution and a well-moistened thick pad placed over it. The drawbacks of this method are the staining of the skin which is usually left, and the very irritating effect of frequent applications. To obviate these, colourless solutions are frequently used in preference.

2. **Potassium Iodide.**—This salt dissolves in water to form a colourless solution from which iodine ions are driven into the tissues by the kathode. It is frequently used when iodine only is required.

3. **Lithium Iodide.**—This salt also forms a colourless solution from which iodine ions are introduced into the tissues by the kathode, and lithium ions by the anode. Both these substances are of therapeutic value in gouty and rheumatic conditions, so there is a distinct advantage in introducing them simultaneously. Both pads are soaked in the same solution, and are then placed on either side of the affected part. The current passes straight through the diseased area, carrying into it lithium from the anode and iodine from the kathode.

Iodine ions are used for antiseptic and for stimulating purposes. The blood vessels of the part treated are dilated and the circulation hastened; the absorption of thickenings is promoted and phagocytosis is increased. Iodine is largely used as an alternative to salicylate of soda in rheumatic conditions.

In every case where much iodine is used for long periods the symptoms of iodism (*i.e.* iodine poisoning) must be watched for. These are smarting of the eyelids, running of the eyes, frontal headache, increase of saliva and later a skin rash. The susceptibility to iodine varies greatly in different people. If any of the above symptoms appear, further treatment must be stopped and a report made to the doctor.

III. **Chlorine Ions.**—These are driven into the tissues from a solution of common salt for which the chemical name is sodium chloride.

Chlorine has an antiseptic action, but it is mainly used for its effect upon recently formed inflammatory fibrous tissue, which is softened by continued ionisation with salt.

Chlorine ionisation is therefore indicated for treatment of the following:

1. Adhesions round joints and tendons.
2. Contracting scars, especially those large superficial scars produced by burns.

3. Dupuytren's contracture of the palmar fascia.

4. Keloid, that is, the overgrowth of projecting scar tissue which occasionally occurs after wounds.

IV. **Lithium Ions.**—These have been especially successful in the treatment of gouty conditions. They are sometimes found efficacious in rheumatic affections, rheumatoid arthritis, lumbago, and sciatica. The soluble salts of lithium which can be used for ionisation are the sulphate, chloride, citrate, salicylate, and iodide. Any of these may be used on the positive side for the introduction of lithium. The salicylate and iodide may be also used on the negative side at the same time for the introduction of either salicyl or iodine ions by the kathode.

V. **Zinc Ions.**—The effects of zinc are antiseptic and stimulating. The ions may be introduced by the anode from any soluble salt of zinc, the sulphate and chloride being those most frequently used. It is generally recommended that an electrode of zinc should be used when driving in zinc ions.

A zinc rod or a zinc needle is occasionally used where the treatment requires the penetration of a cavity.

Zinc ions have been used with success in the following conditions:

1. Chronic intractable ulcers.
2. Rodent ulcer.
3. Inflamed and suppurating corns.
4. Prominent warts.
5. Suppurating sinuses.
6. Intra-uterine infections.
7. Boils and carbuncles.

VI. **Copper Ions.**—These are introduced from a solution of copper sulphate. A copper electrode should be used with the anode.

Copper is also antiseptic and stimulating, and is used for much the same purposes as zinc.

It is also found useful for chillblains, ringworm, pyorrhœa alveolaris, and alopecia areata.

VII. **Magnesium ions** are introduced by the anode from a solution of magnesium sulphate (Epsom salts) in the treatment of multiple warts.

VIII. **Cocaine ions** are introduced by the anode from a solution of cocaine hydrochloride and have been used for intractable neuralgias. The bell electrode is suitable for this purpose.

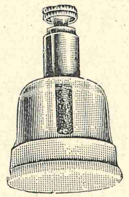

FIG. 26.—THE BELL ELECTRODE, SUITABLE FOR THE APPLICATION OF COCAINE AND OTHER EXPENSIVE DRUGS USED FOR SMALL AREAS.

The solution is introduced into the bell into which a carbon rod dips. The open mouth of the bell is covered by a permeable animal membrane through which the current and the ions pass.

IX. **Morphine ions** are used for the same purpose as cocaine. They are introduced by the anode from a solution of morphine hydrochloride.

X. **Quinine ions** have been used successfully in cases of trigeminal neuralgia which salicyl ions have failed to cure. They are introduced by the anode from a solution of quinine bisulphate.

XI. **Aconite Ions.**—These have been used with success in some cases of chillblains.

It may be mentioned here that where metallic ions are driven into the tissues, it is a general rule that the electrode chosen should be of the same metal. If this is impossible, as in the case of magnesium, very thick padding should be used to avoid the introduction of a different group of ions from the electrode. With thick pads the ions of the electrode will probably not penetrate right through and reach the skin in a single treatment. The padding will, however, gradually become full of these metallic ions, so if used again, it must be thoroughly well washed between treatments. Chamois leather should not be used in ionic medication, because it is very difficult to free from ions.

Where solutions are used in the form of a hand bath, the electrode should certainly be of the same metal as is present in the salt. Where this is impossible, the electrode should be a carbon rod, from which ions are not liberated by the current.

CHAPTER XIV

THE THEORY OF IONISATION

THE only substances which can be used for ionic medication are certain soluble substances which are known chemically as acids, bases, and salts. These, when dissolved in water, split up into electrified particles called ions which have the power of conducting an electric current. They are also called electrolytes.

An acid is a substance of very definite chemical composition and of definite characteristics. For example, it has an acid taste; when concentrated, it has a corrosive action; it turns blue litmus red; and it has the power of uniting with a metal to form an entirely new substance called a salt.

A very good example of an acid is concentrated sulphuric acid. This is a colourless syrupy liquid, which chars such substances as cork, cotton, wool, and the skin. It turns blue litmus red. If very much diluted, it may be tasted, when the " acid " taste will be apparent. It dissolves metallic copper and forms a new substance, copper sulphate, which is a brilliant blue crystalline material, commonly known as blue stone or blue vitrol.

A Base.—This is the name given to those substances that have the power of combining chemically with acids to form new compounds known as salts.

All metals, such as copper, silver, lead, zinc, are bases. Sodium and potassium are rare metals, which are only familiar to us when combined with hydrogen and oxygen, etc. They are bases, and have the special name of alkalis.

There is still another group of substances which, though not metallic, yet act like metals in that they combine chemically with acids to form salts. These substances are known as alkaloids, and comprise those powerful drugs, morphine, strychnine, quinine, cocaine, aconite, etc.

From the point of view of ionic medication there are therefore two groups of substances coming under the classification of base:

1. Metals. 2. Alkaloids.

Salts.—It will be gathered from the above paragraphs that a salt is a chemical substance resulting from the union of a base and an acid.

Table salt, so often simply called salt, is only one member of a very large class. Because of its abundance it is called common salt. Its chemical name is sodium chloride, and it is the result of the union of the metal sodium with hydrochloric acid.

When a soluble salt has been dissolved in water, it is obvious that some change has occurred in its nature. It has disappeared from view, and though a solid substance has been added to water, yet the fluid remains quite clear.

The change which has taken place is a startling one. The chemical attraction which united the metal with the acid to form the salt has been overcome, and metal and acid have definitely parted company. This process of separation is called dissociation. But something still more surprising has occurred at the same time. A separation of electricity has also taken place. The original salt, before solution, is assumed to have been electrically neutral. When separation between metal and acid occurs, the metal takes a positive charge and the acid takes a negative charge. These electrically charged fragments floating about in the water are called *ions*, and, thus charged, the fragments have peculiar properties.

The word "ion" was first used by Faraday, and signifies a wanderer or traveller. The ions of a dissociated substance are to be regarded as wandering aimlessly about in the water. Each positive ion remains in the neighbourhood of its corresponding negative ion, because unlike electricities attract each other. These innumerable wandering ions, positive linked with negative, have been likened by Leduc to dancing partners in a ballroom. They continue to dance so long as they are left undisturbed.

But pass an electric current through them, and a sudden change occurs. The partners are torn from each other; the positively charged ions are irresistibly attracted to the electrode of opposite electrification, the kathode; while the negatively changed ions perforce make their way to the anode. This, says Leduc, is similar to the effect produced in the ballroom by the cessation of the music—at once all the partners separate, the ladies are attracted to the nearest mirror, whereas the men lose no time in reaching the buffet!

To make this clearer, imagine a vessel of water containing a solution of silver nitrate. Into this solution imagine two electrodes to be placed. The current leaves the battery and enters the solution by the anode; it passes through the solution and leaves it by the kathode.

As soon as the current is running from anode to kathode, the + silver ions are attracted to the kathode, upon which they deposit themselves in the form of metallic silver. The — acid ions make their way to the anode, which, if it be a metal, they have the power of dissolving.

The + ions which appear at the kathode receive the name *kations*; the — ions appearing at the anode are called *anions*.

Thus, the kations are seen to travel with the stream of electricity; the anions travel against the stream.

These phenomena depend upon the fundamental electrical principle that like electricities repel and unlike electricities attract each other.

This phenomenon is made of practical use in the process of electro-plating.

A solution of a silver salt is used as the electrolyte, dissociation occurs and free silver ions with a positive charge are liberated.

The object to be plated is immersed in the solution, and is attached to the negative pole of the battery, thus forming the kathode. When the current passes, the + silver kations are attracted to the kathode and are smoothly and evenly deposited thereon. In ionic medication the same principle holds good. The human body forms part of the circuit, the current passing through it from anode to kathode.

If one wishes to drive kations into the tissues, they must be placed under the anode which will repel them.

If anions are to be introduced, they can only be driven in with the kathode.

If a mistake is made, and kations (metals) are used with the kathode, the mutual attraction between kations and kathode will be exerted and the drug will remain on the pad.

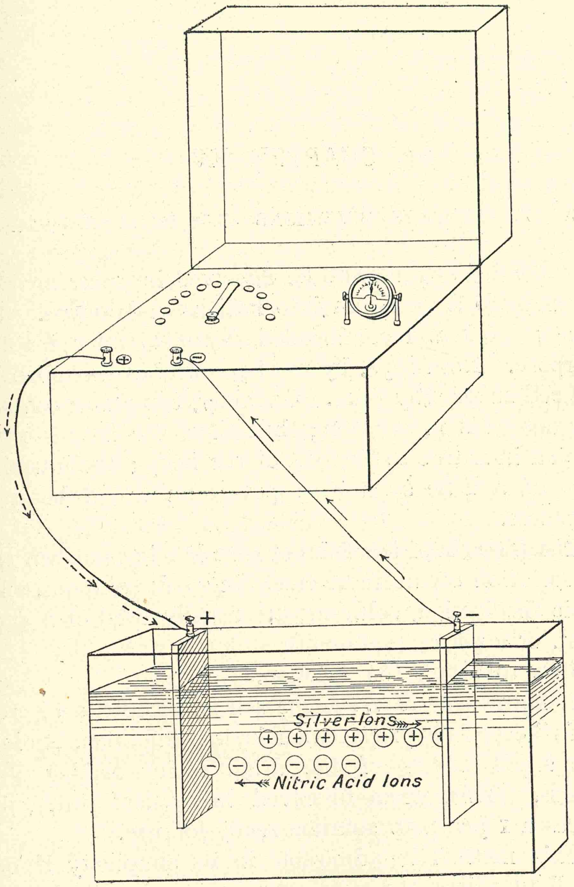

FIG. 27.—MIGRATION OF IONS.

Note the + silver ions making their way to the kathode, and the — acid ions travelling to the anode.

CHAPTER XV

HOW TO PREPARE SOLUTIONS FOR IONIC MEDICATION

THE solid drugs have to be dissolved in water in order to undergo dissociation into kations and anions. The earlier workers recommended distilled water for this purpose. Nowadays, by most people tap water is considered sufficiently pure. Certainly, tap water contains various salts in solution; but these are harmless and similar in nature to the salts of the body; the introduction of a little sodium or potassium would be quite harmless.

The Strength of the Solution.—It has been shown that dissociation occurs more freely in weak solutions. For ionic medication, solutions are usually used of a 1 per cent. or 2 per cent. strength.

How to obtain the Solution.

1. Burroughs & Wellcome sell small bottles of "Soloids" especially prepared for ionic medication. Soloids are small tablets of the drug, each weighing 4·375 grains. This, when dissolved in 1 oz. of water, produces a 1 per cent. solution ready for use.

This method is admirable in its simplicity if only small quantities of the solution are required, and especially where the alkaloids are being used, as the dosage is definitely controlled; but if a foot bath, containing several quarts, is ordered, such a method would be practically prohibitive because of the expense.

2. *Stock Solutions.*—It is cheaper to keep concentrated stock solutions of the commoner drugs such as salicylate of soda and chloride of lithium.

A very convenient strength for the stock bottle is 20 per cent. In order to produce a 1 per cent. solution, an ounce of the concentrated stock is added to a pint of hot water, when required. The hospital dispenser or a dispensing chemist will supply 20 per cent. solutions of any of the drugs used in ionic medication.

3. *Drugs bought by the Pound.*—The cheapest method is to buy the drugs in large quantity and make up one's own stock solutions. This can be easily done by those at all familiar with dispensing.

To make a 20 per cent. stock, weigh out 4 oz. of the solid and add to a pint of water. Use this as above described, 1 oz. of the stock to every pint of solution required.

4. *Small Quantities.*—If preferred, small $\frac{1}{4}$ oz. packets of the drug may be bought ready weighed. When required, one packet can be dissolved in a pint of hot water, forming a 1 per cent. solution.

TABLES OF WEIGHTS AND MEASURES

I. Avoirdupois (Weight).—

20 grains make 1 scruple.
60 grains make 1 drachm.
437·5 grains make 1 ounce.
16 ounces make 1 pound.

It is accurate enough for our purposes to calculate that 500 grains make one ounce, thus avoiding the use of decimals.

II. Measures.—

60 minims make 1 fluid drachm.
8 drachms make 1 fluid ounce.
20 fluid ounces make 1 pint.

N.B.—1 minim equals one drop, approximately.
1 drachm equals one teaspoonful.
1 ounce equals two tablespoonsful.

Symbols.—

gr. = grain
♏ = minim
℈ = scruple
ʒ = drachm
℥ = ounce
O = pint

CHAPTER XVI

ELECTROLYTIC BURNS

The student will now understand more fully the meaning of electrolysis, that is, the breaking up of compounds ① into their constituents by means of the electric current. It is by the process of electrolysis and the liberation of caustic substances that electric burns are produced.

The human body is to be regarded as a sac containing fluids which hold a great variety of salts in solution. Sodium and potassium are present in great quantity.

Let us suppose sodium chloride to be the chief of these natural salts of the body. As the constant current passes through the tissues, it splits up the sodium chloride into + sodium ions and — chlorine ions. The + sodium ions are attracted to the kathode; here they are liberated on the surface of the body. If, at this place, there is sufficient moisture present, a well-soaked pad or a water bath, the sodium ions will leave the skin without harming it, and become dissolved in the water, with which they unite.

If, on the contrary, there is insufficient water present, this metal is deposited in the tissues, and being of a very caustic nature, it produces as severe a burn as phosphorus or nitric acid.

These burns occur more frequently at places where the current is especially concentrated, because more ions are directed to such spots. They naturally occur where bare metal touches the skin, because at such a place there is great concentration of current.

They do not occur when the electric bath is used, unless the metal electrode remain in contact with the skin for any length of time.

Electric burns cause a destruction and devitalisation of the tissues to a very considerable depth; they are therefore slow in healing, they readily become septic, and very often they leave large and unsightly scars.

Thus, their prevention of is the greatest importance.

Treatment.—When a burn has unfortunately been produced, the greatest care must be taken to keep the part aseptic. The damaged tissues are particularly liable to the attacks of micro-organisms, and, if once infected, the tissues have the greatest difficulty in resisting the further invasion of the microbes.

When first the burn is observed, the skin around must be carefully cleansed with a weak antiseptic, such as 1 in 40 carbolic lotion. The wound is then to be dressed and kept covered.

A dry dressing is unsatisfactory, as it sticks to a raw surface, and tears off the newly forming epithelium every time it is changed.

A frequently renewed carbolic compress acts very satisfactorily.

An antiseptic ointment, such as boracic, eucalyptus, or resin ointment, may be used.

If the part unfortunately becomes septic in spite of care, ointments are contra-indicated, and four-hourly boracic fomentations must be used until the part is again quite clean.

Even a small electrolytic burn takes weeks to heal with the most careful attention. If it has been deep, it leaves a scar. Every precaution must be taken to avoid this most unfortunate occurrence.

CHAPTER XVII

THE EFFECT OF THE GALVANIC CURRENT UPON MUSCLES

HITHERTO we have only been considering the effects and uses of stabile galvanism. It will have been realised by now that while the constant current is flowing with unvarying strength, the main effect upon muscle is a metabolic one. No contractions are set up.

If we wish to produce muscular contractions by this current in order to exercise and develop the muscle and to obtain an increased venous and lymphatic flow, we must use some means of either repeatedly interrupting the current or of continually varying its intensity.

First of all, let the effect of galvanism upon *normal* muscle be clearly understood. Later we shall observe its effect upon degenerated muscle.

I. **Effect of Galvanism upon Normal Muscle.**—The constant current produces no contractions while flowing with uniform strength.

If the current be suddenly cut off, a muscular contraction is produced.

If the current be suddenly switched on, a muscular contraction is produced.

It is found that when the active electrode is the + kathode, the contraction when the current is suddenly turned on is very much greater than when the active electrode is the anode. −

This is usually expressed by saying that the kathodal closure contraction is greater than the anodal closure contraction, or more shortly—

K.C.C. > A.C.C.

A closure contraction is one which is produced when the circuit is closed and the current made.

In order to obtain opening contractions—that is, those which follow opening of the circuit or breaking of the current—still larger currents are necessary.

The contraction given with the anode in this case is greater than that given with the kathode.

That is to say, the anodal opening contraction is greater than the kathodal opening contraction, or shortly—

A.O.C. > K.O.C.

The order in which these contractions appear, as the current is gradually increased, is—

K.C.C. > A.C.C. > A.O.C. > K.O.C.

Most normal muscles give a K.C.C. with about 3 m.a. In order to obtain a K.O.C. the current must be so strong as to almost produce a tetanising effect when the current is made.

The type of the contraction produced is to be noticed. If the muscles are normal, this is short, sharp, and brisk; a quick response followed by a quick relaxation.

Treatment of Normal Muscles.—For muscles which are weak, wasted, and flabby, but which are not actually degenerated, the faradic current is the most efficacious, producing contractions more readily and with less discomfort than the galvanic.

However, in many instances it is advisable to make use of both treatments.

When the galvanic current is used, it must be interrupted at repeated and regular intervals by some means.

One of the following methods may be chosen for the purpose:

1. Labile method with a movable electrode.
2. With the use of the reversing switch.
3. With the use of a metronome or rhythmic interrupter.

1. **The Labile Method.**—Place a large anodal pad beneath that part of the spine which supplies the affected muscles.

Attach the kathode to a well-padded roller or disc. This is to be continually dabbed on and off the affected muscles, causing contractions. Before beginning the movements, hold the active electrode on the part steadily for a minute until a sufficient amount of current is being passed. Note the strength of this by the galvanometer reading; it will probably be about 10 or 15 m.a. that the patient can comfortably take.

Then turn the galvanometer out of the circuit to prevent any undue strain on its mechanism.

The motor point of every affected muscle is to be especially picked out and treated by the active electrode in order to get the best contractions.

Motor Points.—The motor point of a muscle is that point at which the nerve enters the muscle. Stimulation at this spot results in the maximum contraction of the muscle. This is because, where both muscle and nerve are normal, the muscle responds to the electrical stimulus conveyed *through* the nerve fibres.

There are many charts and diagrams showing the motor points of the more important muscles; but as the position of these varies in different people, it is more satisfactory for the experimenter to find for himself that spot at which the greatest result follows electrical

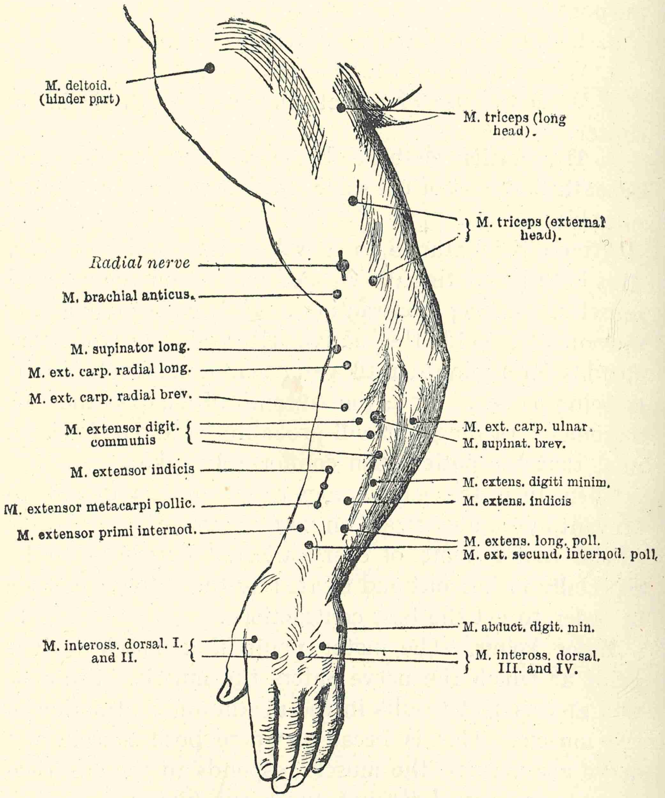
M. deltoid. (hinder part)
Radial nerve
M. brachial anticus.
M. supinator long.
M. ext. carp. radial long.
M. ext. carp. radial brev.
M. extensor digit. communis
M. extensor indicis
M. extensor metacarpi pollic.
M. extensor primi internod.
M. inteross. dorsal. I. and II.
M. triceps (long head).
M. triceps (external head).
M. ext. carp. ulnar.
M. supinat. brev.
M. extens. digiti minim.
M. extens. indicis
M. extens. long. poll.
M. ext. secund. internod. poll.
M. abduct. digit. min.
M. inteross. dorsal. III. and IV.

FIG. 28.—MOTOR POINTS OF ARM.

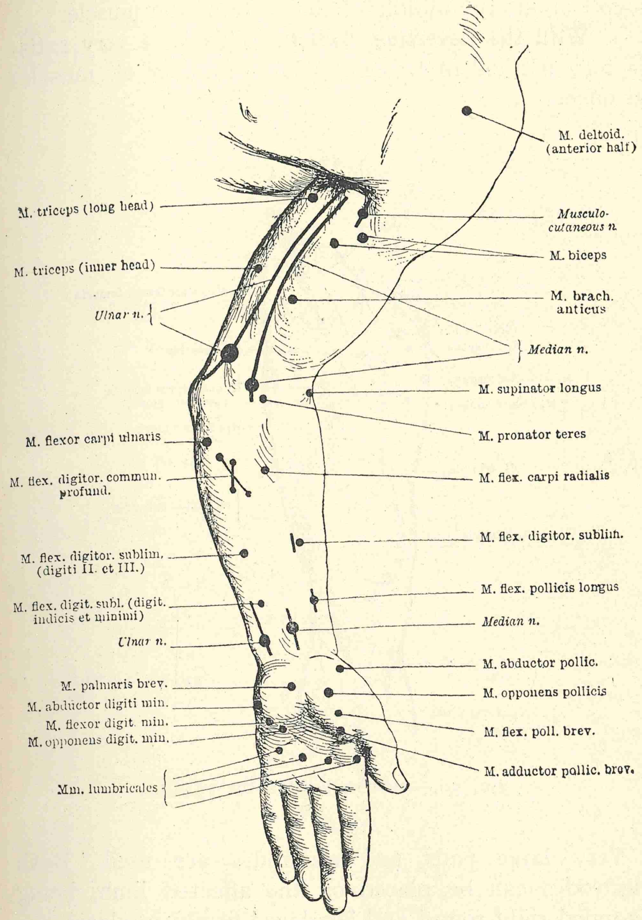
M. triceps (long head)
M. triceps (inner head)
Ulnar n.
M. flexor carpi ulnaris
M. flex. digitor. commun. profund.
M. flex. digitor. sublim. (digiti II. et III.)
M. flex. digit. subl. (digit. indicis et minimi)
Ulnar n.
M. palmaris brev.
M. abductor digiti min.
M. flexor digit. min.
M. opponens digit. min.
Mm. lumbricales
M. deltoid. (anterior half)
Musculo-cutaneous n.
M. biceps
M. brach. anticus
Median n.
M. supinator longus
M. pronator teres
M. flex. carpi radialis
M. flex. digitor. sublim.
M. flex. pollicis longus
Median n.
M. abductor pollic.
M. opponens pollicis
M. flex. poll. brev.
M. adductor pollic. brev.

FIG. 29.—MOTOR POINTS OF ARM.

stimulation. In the majority of cases, this is to be found about the middle of the body of the muscle.

2. **With the Reversing Switch.**—This is a very satisfactory method of treating a large number of muscles at once.

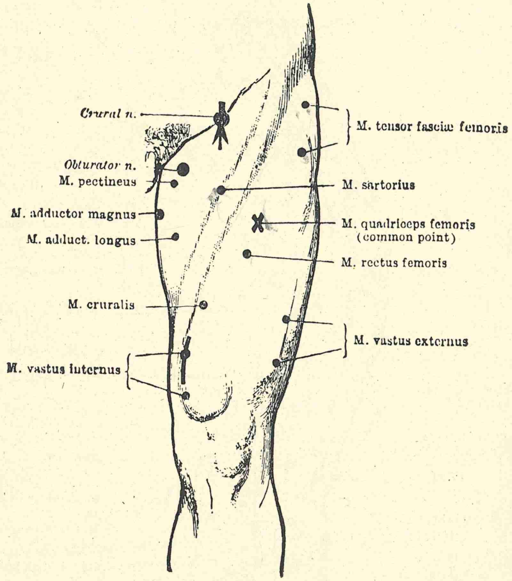
Crural n.
Obturator n.
M. pectineus
M. adductor magnus
M. adduct. longus
M. cruralis
M. vastus internus
M. tensor fasciæ femoris
M. sartorius
M. quadriceps femoris (common point)
M. rectus femoris
M. vastus externus

FIG. 30.—MOTOR POINTS OF THIGH.

Very large pads and electrodes are used. Both electrodes can be placed on the affected limb, being wrapped right round and bandaged firmly in place.

The current is then turned on till the patient is conscious of it; the amount of current required to produce the pricking sensation varies with the size of the pads;

it is often about 5 or 10 m.a. Then turn the galvanometer out of the circuit and move the reversing switch regularly back and forth some twelve or twenty times a

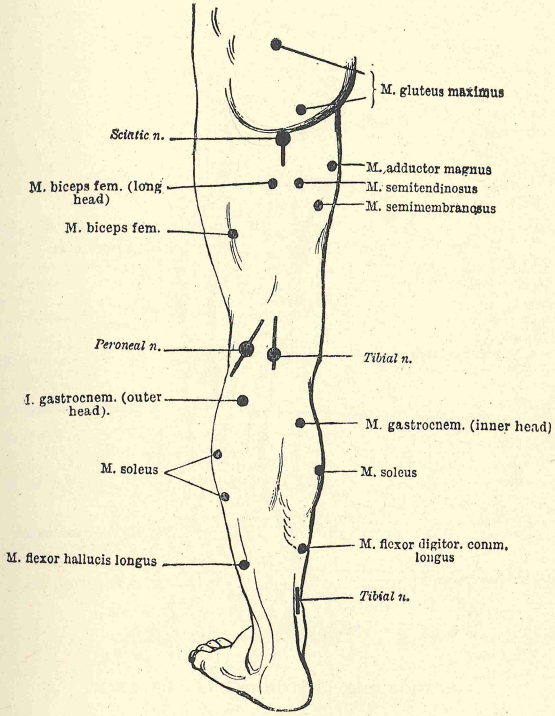
M. gluteus maximus
Sciatic n.
M. adductor magnus
M. biceps fem. (long head)
M. semitendinosus
M. semimembranosus
M. biceps fem.
Peroneal n.
Tibial n.
M. gastrocnem. (outer head).
M. gastrocnem. (inner head)
M. soleus
M. soleus
M. flexor digitor. comm. longus
M. flexor hallucis longus
Tibial n.

FIG. 31.—MOTOR POINTS OF LEG.

minute. By this means the current is very rhythmically made and broken. The makes and breaks must be sufficiently slow to allow the muscles to relax completely between the contractions.

3. **With the Metronome Interrupter.**—The simple metronome has been adapted for use in electrical treatments as follows:

Across the base of the pendulum there is attached a metal cross-piece, carrying foot-pieces which dip into metal cups filled with mercury. To each cup is attached a binding screw.

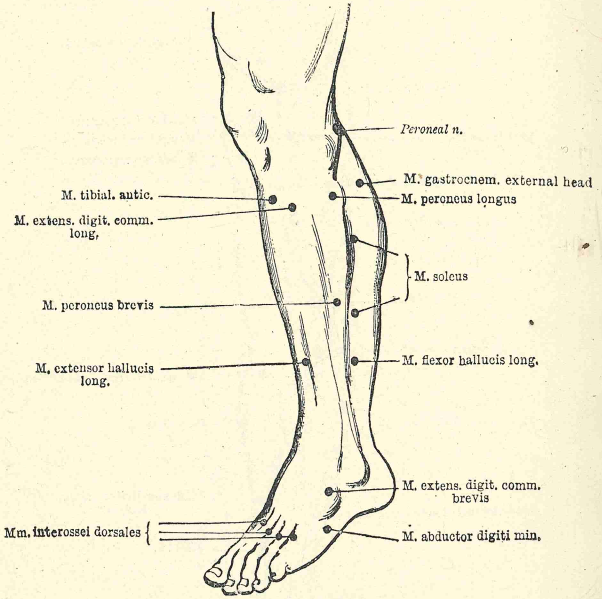
Peroneal n.
M. gastrocnem. external head
M. peroneus longus
M. tibial. antic.
M. extens. digit. comm. long.
M. soleus
M. peroneus brevis
M. extensor hallucis long.
M. flexor hallucis long.
M. extens. digit. comm. brevis
Mm. interossei dorsales
M. abductor digiti min.

FIG. 32.—MOTOR POINTS OF LEG.

The metronome is connected in series with the patient in the following manner. One wire from the battery is attached to one of the outside cups; the middle cup is attached to the patient, who in turn is attached to the battery. The third cup is not used. When the metronome is wound up, the pendulum swings from side to side, regularly carrying the cross-piece up and down. One of the attached foot-pieces is constantly being withdrawn from and re-introduced into its corresponding cup of mercury, thus rhythmically making and breaking the current. The rate of the interruptions can be varied by means of the sliding weight on the pendulum.

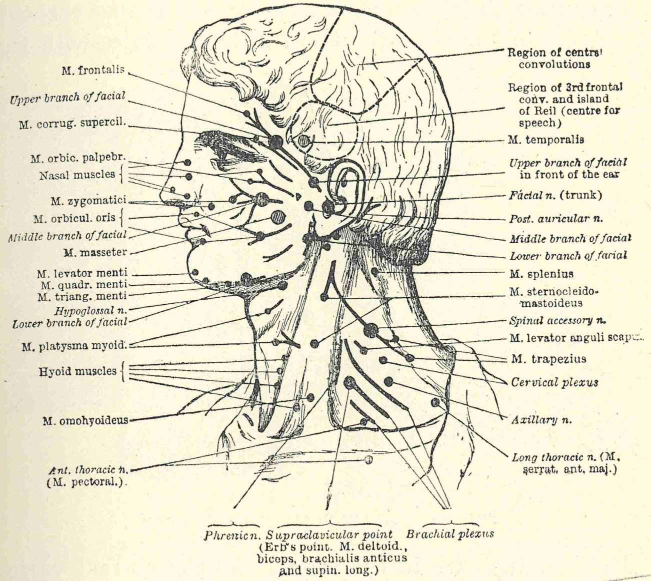
M. frontalis
Upper branch of facial
M. corrug. supercil.
M. orbic. palpebr.
Nasal muscles
M. zygomatici
M. orbicul. oris
Middle branch of facial
M. masseter
M. levator menti
M. quadr. menti
M. triang. menti
Hypoglossal n.
Lower branch of facial
M. platysma myoid.
Hyoid muscles
M. omohyoideus
Ant. thoracic n. (M. pectoral.)
Region of central convolutions
Region of 3rd frontal conv. and island of Reil (centre for speech)
M. temporalis
Upper branch of facial in front of the ear
Facial n. (trunk)
Post. auricular n.
Middle branch of facial
Lower branch of facial
M. splenius
M. sternocleido-mastoideus
Spinal accessory n.
M. levator anguli scap...
M. trapezius
Cervical plexus
Axillary n.
Long thoracic n. (M. serrat. ant. maj.)
Phrenic n.
Supraclavicular point (Erb's point. M. deltoid., biceps, brachialis anticus and supin. long.)
Brachial plexus

FIG. 33.—MOTOR POINTS OF FACE.

The rhythmic interrupter is a piece of apparatus by means of which the current is made to gradually rise from zero to a maximum and as gradually to fall back to zero, thus obviating sudden makes and breaks.

It consists of clockwork which operates a metal arm in an up-and-down direction. Attached to this horizontal arm is a vertical platinum wire dipping into a cup of water. As the mechanism works, this wire alternately rises and sinks. The current passes from the wire, through the water, to the cup, and thence through the rest of the circuit. The resistance varies with the depth of the wire in the water, and the current varies with the resistance. Thus the patient is receiving a current of regularly varying intensity.

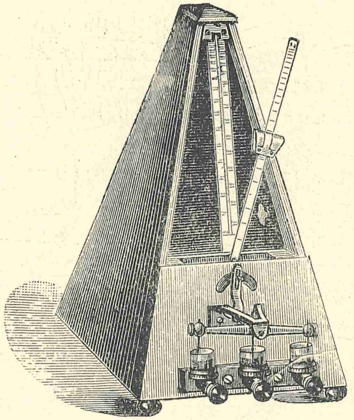

FIG. 34.—METRONOME INTERRUPTER.

Rhythmic interrupters are now constructed so that they can be operated by an electric motor instead of clockwork.

II. **The Effect of Galvanism on Degenerated Muscle.**—The nutrition and tone of a muscle fibre is governed by nervous impulses originating in the motor nerve cells situated in the anterior horn of the spinal cord. If

these impulses are cut off from the muscle, either by injury or disease of the nerve or by a damaged condition of the anterior horn cell, the muscle substance soon undergoes degeneration. The muscle is paralysed; it wastes extremely rapidly and markedly; it loses its normal tone and hangs loosely and flabbily between its bony attachments; the circulation through it is defective and the part is cold. A good example of such a condition is found in infantile paralysis.

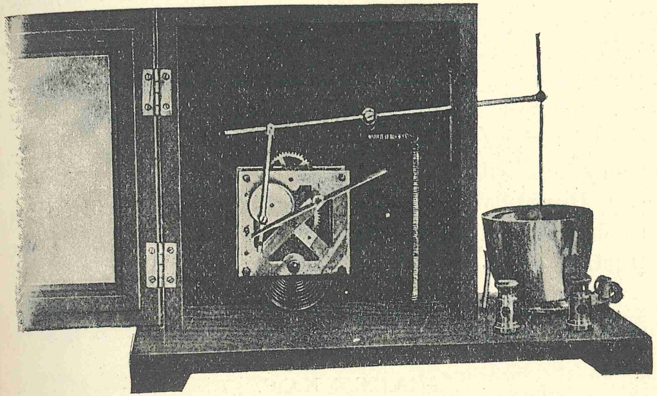

FIG. 35.—RHYTHMIC INTERRUPTER.

When this condition is present, the muscle gives an abnormal response to electrical stimulation. This response is called the reaction of degeneration, the name given to it first by Professor Erb in 1868. For convenience, it is usually designated by the initials R.D.

Reaction of Degeneration.—There are three main points in which the degenerated muscle varies in its response from the normal muscle.

1. There is absolute loss of all response to stimulation by the faradic current. This is because faradism only

stimulates the muscle through the nerve, and, in the case we are considering, the nerve has lost its conductivity to electric currents.

2. The muscle responds to interrupted galvanism by a slow, sluggish, and long-continued contraction, which passes off gradually. In the normal muscle the response is brisk. This is because the electric current stimulates the normal muscle through its nerve fibres. These fibres act as excellent conductors of the current to all parts of the muscle, and the response is therefore rapid.

Where the muscle and nerve are degenerated, the nerve does not conduct the electrical impulse. The galvanic current affects the muscle directly, but the effect is slow, as the current is transmitted more sluggishly through the muscle tissue.

3. In normal muscle the kathodal closure contraction is obtained more readily than the anodal closure contraction.

In most cases of degenerated muscle this is reversed, and the anodal closure contraction is obtained first—*i.e.* :

A.C.C. > K.C.C.

Muscle and Nerve Testing.—The diagnosis of the seat of a nerve lesion and the prognosis of the condition are in many cases aided by a knowledge of the muscle reactions. The tests are, however, tedious to perform, and the results are often obscure. For electrical testing, the steps are threefold.

1. Test the response to faradism of the muscle groups under observation, comparing, if necessary, with healthy muscles.

2. Note particularly the type of the muscular contraction obtained in response to the interrupted galvanic current, whether brisk or sluggish. Compare with a healthy muscle.

3. Observe whether K.C.C. or A.C.C. is more readily obtained.

Technic of Muscle Testing.—In order to perform the test, it is of the greatest importance that the affected part should be completely supported; there must not be the slightest drag on the muscles.

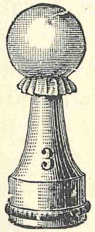

FIG. 36.—ELECTRODE FOR MUSCLE TESTING.

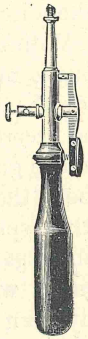

FIG. 37.—ELECTRODE HANDLE WITH MAKE AND BREAK KEY.

The indifferent electrode is a large flat padded metal plate; this is to be placed under that part of the spine which supplies the muscles to be tested.

The active electrode is usually a small metal disc, well padded, and mounted on a handle with a make and break key. This is placed on the motor point of the muscle to be tested, and the current turned on to about 3 m.a.

In the first part of the test, the active electrode is to be the kathode. By means of the make and break key, the current can be made and broken as required. Carefully watch for the first slight response to the kathodal closure. Gradually turn the current on until this is obtained. The contraction of the muscle is usually best indicated by a slight tightening of its tendon, or a twitching of the joint it works. At the first sign of a response, the strength of the current is to be observed and recorded.

The second part of the test is performed with the anode for the active electrode. By means of the reversing switch, the disc is speedily converted to the desired polarity. With the disc as anode, the same proceeding is gone through, and again the strength of the current which gives the first slight response on "make" is observed and recorded.

If the anode gives a response with a less current than the kathode, then R.D. may be diagnosed, provided also that the response to faradism is lost, and the sluggish contraction to galvanism is obtained.

Conditions in which R.D. may be Found.—From what has already been said, it will be assumed that R.D. is likely to be present in those conditions where there is marked damage of either the anterior horn cell or of the nerve trunk springing from these cells; this part of the nervous system is called the lower motor neurone, in contradistinction to the upper motor neurone—*i.e.* the motor cell in the Rolandic area of the brain and the nerve fibre springing from it and passing down the cord as the pyramidal tract. Lesions, if long continued, of the lower motor neurone result in R.D.; lesions confined to the upper motor neurone do not show R.D. The commoner lesions of the lower motor neurone may be

1. *Lesions of the anterior horn cells:*

(*a*) Anterior poliomyelitis (infantile paralysis).

(*b*) Progressive muscular atrophy.

2. *Lesions of the nerve trunk:*

(*a*) Section of the nerve trunk—*e.g.* ulnar or median paralysis from a cut.

(*b*) Long-continued pressure on a nerve trunk—*e.g.* drop wrist from involvement of the musculo-spiral nerve in callus; *e.g.* severe cases of facial paralysis, from compression of the facial nerve in the stylo-mastoid foramen.

(*c*) Degeneration of a nerve trunk—long-continued peripheral neuritis, alcoholic, post-diphtheritic, plumbic, or arsenical.

Treatment of Muscles with R.D.—It is commonly said that it is useless to apply faradism in these cases, as no response is to be obtained. This is disputed by Lewis Jones, who recommended the use of the induction coil for the most markedly degenerated muscles.

Interrupted galvanism is the more usual method of treatment, as by its use good contractions can generally be obtained. Thus, the muscles will be exercised and their circulation and nutrition increased.

Any of the methods already described for the application of interrupted galvanism may be used.

In addition, combined galvanism and faradism as described under the section on "Faradism" may be used, and excellent results often ensue from this method of treatment.

PART II

FARADISM

CHAPTER XVIII

INDUCTION

Two methods have already been mentioned by which 1
electricity can be produced—*i.e.* friction and chemical
action. The third method is called induction. This 2
method is largely used at the present time for the pro-
duction of electric currents for commercial purposes by 3
means of dynamos.

It was in 1831 that Michael Faraday made several
extremely important observations on the action of 4
magnets and electric currents which have since revolu-
tionised science and which have led to the invention of
the dynamo, the telephone, the high-frequency and 5
X-ray apparatus, and most of the modern electric 6
appliances.

Faraday's Discoveries.—1. If a magnet be moved 7
backwards and forwards in a coil of wire forming a
closed circuit, electric currents are produced in the coil. 8
These can be detected by a sensitive galvanometer
placed in the circuit.

The movements of the galvanometer needle show that the current produced when the magnet is introduced into the coil runs in one direction, whereas the current produced when the magnet is withdrawn runs in the opposite

direction. If the magnet remains stationary, no current
is produced. If, however, the coil be made to move in
relation to the stationary magnet, alternating currents 9
are produced, as before. This is the principle upon
which the dynamo works.

2. Faraday's second observation is the reverse of the
first. If a coil of wire be wound round a bar of soft 10
iron (not a magnet) and a current be passed along the
wire, the soft iron bar becomes strongly magnetised so
long as the current is running. When the current
ceases to flow, the iron loses its magnetism.

Such a bar, made magnetic by the constant current,
is called an electro-magnet. Electro-magnets are used 11
commercially for raising large and unwieldy plates of
iron; in surgery for removing steel particles from the
eye, etc.; and in electrical apparatus for operating the
vibrating armature of the faradic coil.

3. Faraday's third observation is this. If a closed
coil of wire carrying a current be brought into the 13
neighbourhood of a second closed coil, electric currents
are produced in the second coil whenever the current
in the first coil is *made* or *broken*. At *break*, the induced 14
current passes round the second coil in the same direc-
tion as the inducing current in the first coil; at *make*,
the induced current in the second coil passes round in the 15
opposite direction to the inducing current in the first coil.

The induced current produced in the second coil
is an alternating one; it can be made very strong 16
and forcible, by having a sufficiently large number of
turns in the coil. There is thus an electrical economy,
in that a small inducing current in the first coil can 17
produce currents of great strength in the second coil
by the simple method of increasing the turns of wire
in the second coil.

These phenomena depend upon what is called the inductive action of magnets and electric currents, and are the result of a *magnetic field* set up in the surrounding atmosphere. It is necessary to give some consideration to the properties of magnets. 18

Magnets.—A magnet is a substance which has the power of attracting to itself small particles of iron, steel, nickel, and cobalt. It also has the property of setting itself in a definite relation to the earth, when freely suspended, pointing due north and south. 19

Natural Magnets.—In certain parts of the earth natural iron ore is to be found, which is endowed with these properties. Such a piece of magnetic iron is known as a natural magnet or lodestone. The lodestone was used by the ancients as a compass; it was balanced upon a piece of cork floating in a bowl of water, and in due course it could come to rest, pointing north and south. 20

Artificial Magnets.—Most of the magnets met with nowadays are artificial; of these, there are two kinds—temporary, in which the magnetism is soon lost, and permanent, in which it is retained almost indefinitely. Temporary magnets are made of soft iron, which can be very readily magnetised, but which rapidly loses its magnetism. 1 2

Permanent magnets are made of steel, *i.e.* iron which has been tempered. Steel is very difficult to magnetise, but retains its magnetism for a long period. 3

How Magnets are Made.—1. By stroking for some time an iron or steel bar with a magnet. The stroking must always be performed from end to end in the same direction. 4

2. By passing an electric current along a wire wound round a bar of iron or steel.

Properties of Magnets.—1. If suspended freely, one end of the magnet always points toward the north pole of the earth, and the other toward the south pole. 5

A compass needle is a magnet balanced upon a pivot so that it is always free to set itself due north and south.

The two ends of the magnet are called *poles*, one being called the north-seeking pole, usually marked N, and the other the south-seeking pole.

2. The second obvious characteristic is that particles of iron and steel in its neighbourhood are attracted to the magnet.

Each tiny particle of iron or steel lying in the sphere of influence of a magnet is temporarily converted into a magnet itself, having a north and south pole. The north pole of the permanent magnet attracts the south pole of each small magnet, and vice versa. Each tiny magnet also exerts an attractive influence upon every particle in its neighbourhood. This effect can be shown by the magnetic chain. Take a bar magnet, and allow it to attract an iron tack; the tack will in turn attract a second, the second a third, and so forth until a chain of tacks has been formed.

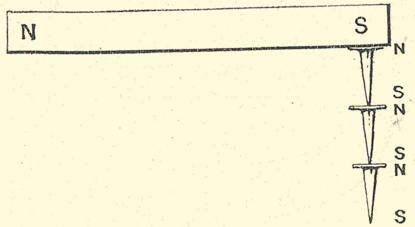

FIG. 38.—A MAGNETIC CHAIN.

The Magnetic Field.—The above effect upon small particles is produced by what is called the *magnetic field* surrounding a magnet.

This is the space around the magnet which is regarded as being filled with *magnetic lines of force.* These lines of force leave one pole of the magnet, and spread out through the surrounding atmosphere, finally converging to enter the other pole. At the poles, the lines of force are close together and concentrated; around the sides of the magnet they are diffused. Thus, the strongest attraction is always to be found at the two poles.

To demonstrate the Lines of Force.—Lay a bar magnet on a table and put a firm piece of cardboard over it.

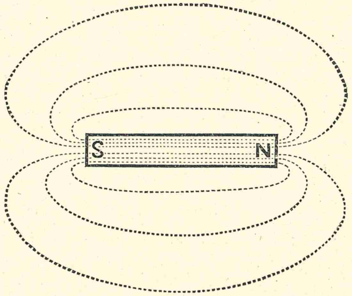

FIG. 39.—LINES OF FORCE OF BAR MAGNET.

On the cardboard scatter a number of very fine iron filings. These filings move about, especially when the cardboard is gently tapped, and arrange themselves regularly end to end along the magnetic lines of force. The particles will be thickly grouped at the spots corresponding to the poles of the magnet, much more thinly at the sides. At a greater or less distance from the magnet, according to its strength, the attractive influence ceases to be exerted. The area in which it is present is called the magnetic field.

The Magnetic Field round a Wire carrying a Current.—In the neighbourhood of a wire carrying a constant current a similar magnetic field is established. The magnetic lines of force in this case run in a circular direction round the wire. It is by means of these lines that electrical induction takes place. Such lines affect a compass needle in the neighbourhood of the current in such a way that the needle leaves its north and south position and sets itself parallel with the lines of force and at right angles to the wire. This has already been demonstrated in connection with Oersted's experiment.

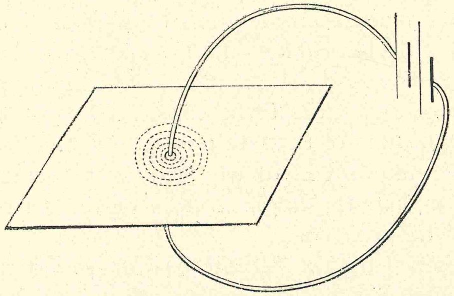

FIG. 40.—A MAGNETIC FIELD ROUND A WIRE CARRYING A CURRENT.

These lines of force around the current can be demonstrated in the following way:

Take a piece of cardboard with a small hole in the centre. Through this thread a wire carrying a constant current. Upon the cardboard scatter some fine iron filings. On gently tapping the cardboard, the filings set themselves in a circular manner around the wire.

Nota Bene.—It is to be noted that the inductive force is transmitted through such substances as silk, cotton, cardboard, and glass, which are insulators to the electric *current.* On the other hand, metals which are good conductors of the current cut off these lines of force.

CHAPTER XIX

THE FARADIC BATTERY

THE mechanism of the faradic battery can only be understood after a due consideration of Faraday's observations and of the laws of induction. The three phenomena already enumerated are found practically applied in the piece of apparatus to be considered.

The application of the first proposition, that a magnet introduced into a coil of wire induces currents in that coil, is found in the augmentation of the currents by means of the iron core.

The second, that a current passing round a bar of iron magnetises it, is exemplified in the vibrating armature.

The third, that at the make and break of a current in one coil alternating currents are produced in a neighbouring coil, is applied in the construction of the secondary winding.

The Essential Parts of the Faradic Battery.—There are a great many different patterns of this piece of apparatus on the market now, such as Dr. Spamer's coil, Lewis Jones's sledge coil, Dubois-Reymond's induction coil. They all act upon the same principles, and the essentials of each are:

1. Some source from which a continuous current can be obtained.

2. A stationary coil of wire wound upon a wooden

bobbin; this is known as the primary winding, and round it the original current passes.

3. A device in the circuit of the primary winding for automatically making and breaking this primary current. The mechanism in common use is known as Wagner's Hammer or the Vibrating Armature.

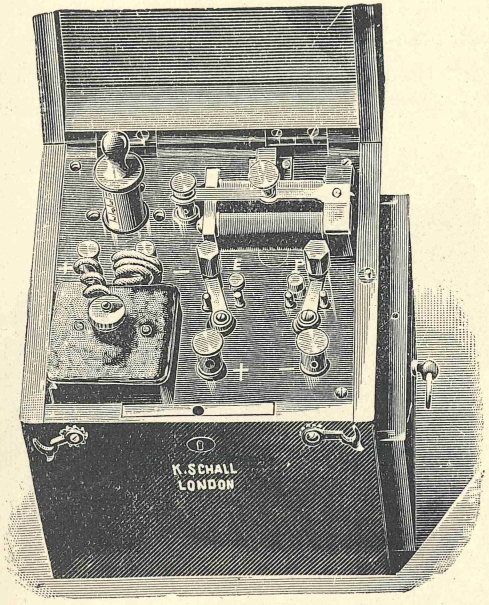

FIG. 41.—DR. SPAMER'S COIL.

4. A second coil of wire, entirely separate from the first, also mounted upon a hollow wooden bobbin. This is known as the secondary coil or winding, and in it "induced" alternating currents are produced.

5. An iron core which can be introduced into the centre of the wooden bobbins. It becomes magnetised

by the currents passing in the coils, and by its magnetism produces a strengthening effect upon these currents.

6. Binding screws or switches by means of which currents may be conveyed to the patient either from the primary or the secondary coil.

These essential parts must now be considered in detail in order to understand their working. A clear knowledge of the mechanism of the battery will save much time and trouble, as the owner will be able to remedy the small defects which arise from time to time, without having recourse to the instrument maker.

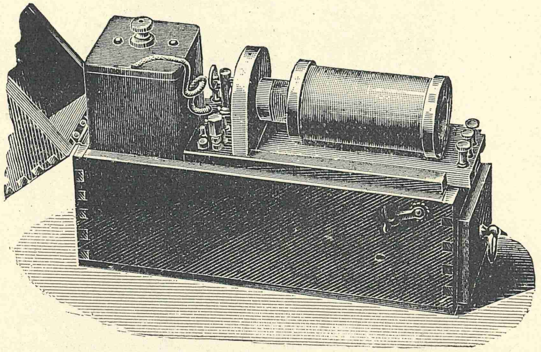

FIG. 42.—DUBOIS-REYMOND'S COIL.

1. **The Source of the Primary Current.**—The primary current must be a constant one in the first place.

It may be obtained from:

(*a*) One or two cells of the Leclanché type arranged in series. Dry cells are most convenient. These cells are attached to the binding screws, usually marked B (battery), from which the current is then led round the primary winding and through the vibrating armature. The current resulting in the primary coil is similar to an intermittent or rapidly interrupted galvanic current. These cells in the course of time run down, the chemicals having been exhausted. The length of life depends upon the amount of use to which the battery is put and the original size of the cells. The ones commonly supplied give from eighty to a hundred hours' use. As the cells become worn out, the current gradually becomes more and more feeble, finally ceasing altogether. When this occurs, the dead cell must be replaced by a new one. Exhaustion of the cell is one of the common causes of disorder in the faradic battery.

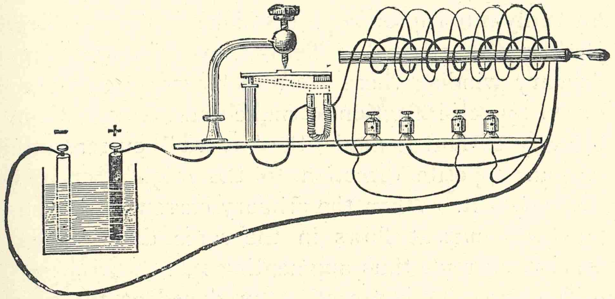

FIG. 43.—DIAGRAM SHOWING PRIMARY AND SECONDARY WINDINGS OF SLEDGE COIL.

(*b*) The direct current from the main is also used to operate the induction coil in place of cells. This current has to be first reduced to a suitable voltage by passage through a suitable resistance.

2. **The Primary Winding.**—The wire forming this is usually a coarse copper one insulated by a silk and

rubber covering. The diameter of the wire is large in order to reduce its resistance so that as large a current as possible may be produced in it from one or two cells. This coil is a complete circuit round which the current from the cells passes and in which is interposed the device for interrupting the current.

There are also two binding screws in connection with this coil, through which a portion of the current can be diverted to the patient. These screws are usually marked P (primary).

It has already been said that the primary current is a rapidly interrupted current which flows in one direction. Besides the original current from the cells, in this primary winding there are also "extra" currents produced by self-induction at make and break. When the primary current is made, the "extra" current induced has an opposite direction to the original current, so weakening it. When the primary current is broken, the "extra" current flows in the same direction as the original current, thus augmenting it.

The muscular contractions produced at the moment of break predominate over those produced at make, and the signs + and —, which are sometimes found by the terminals, indicate the direction of the current produced at break. This self-induction in the primary coil is an electrical economy, a strong current being produced from a single Leclanché cell. The primary current can be still further augmented by introducing into the centre of its bobbin a core composed of a number of slender iron rods. When the current passing round this core is "made," the core becomes magnetised; when the current is broken, the core loses its magnetism. Thus, a constantly changing magnetic field is set up in the neighbourhood of the coil, which has the effect of "inducing" still more currents in the primary winding.

This magnetic induction can pass through the wood of the bobbin and through the insulating coverings of the wire; it will be remembered that these substances, insulators of electric currents, are permeable to magnetism.

It will usually be found that the iron core is composed of a number of slender rods bound together, and not one solid mass of iron. The reason for this is that the slender rods are much more rapidly magnetised and demagnetised than a thick solid bar would be.

3. **Wagner's Hammer.**—This device works upon the principle of the electro-magnet, which is the name given to a soft iron bar temporarily magnetised by the passage of an electric current around it. The vibrating armature is composed of the following essentials:

(*a*) An upright metal support upon which the hammer is held horizontally by a wire spring, in such a manner that it touches a suitably placed screw called a "contact screw."

The head of the hammer is suspended immediately above one or two rods of soft iron, the electro-magnets mentioned below.

(*b*) The electro-magnets are rods of soft iron surrounded by closely wound coils of wire which are derived from the primary winding, and round which the interrupted primary current flows. When the current is made, these rods are magnetised; when the current is broken, they are demagnetised.

(*c*) The primary coil is in connection with the vibrating armature at two points—at the contact screw and at the electro-magnets.

When the cell operating the mechanism is connected with its corresponding binding screws (B), a circuit is completed as follows (see diagram):

(i) Through binding screw, A.

(ii) Up the metal support, *B*.

(iii) Along the limb of the hammer to the contact screw, *C*.

(iv) From the contact screw to the primary coil, *D*.

(v) From primary coil to electro-magnet, *E*.

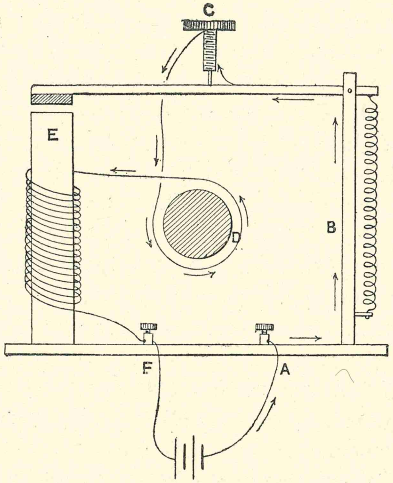

FIG. 44.—WAGNER'S HAMMER: CURRENT MADE.

(vi) From electro-magnet to binding screw, *F*.

(vii) Thence back to the cell.

How the Hammer Works.—At the moment that the current passes from the cell through this circuit, the iron rod *E* is converted into an electro-magnet strong enough to attract the head of the hammer, thus drawing down the limb of the hammer out of touch with the contact screw. When the hammer leaves the contact screw, the following sequence of events takes place:

(i) The circuit is broken at the contact screw.

(ii) The current ceases to flow.

(iii) The iron rod ceases to be a magnet.

(iv) The hammer is released, and is caused to fly back to the contact screw by the tension of its wire spring.

(v) The circuit is remade at the contact screw.

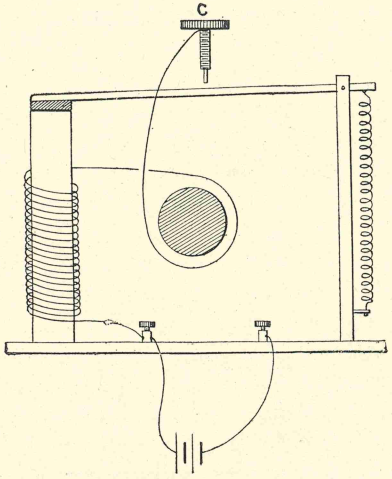

FIG. 45.—WAGNER'S HAMMER: CURRENT BROKEN AT C.

(vi) The current again flows through the circuit.

(vii) The iron rod is remagnetised, attracting the hammer to it and again breaking the circuit.

This sequence of events occurs again and again with great rapidity; thus the constant current from the cell is automatically converted into the rapidly interrupted current of the primary winding.

The Rapidity of the Interruptions.—The rate at which the interruptions are produced can be varied within limits by altering the distance between the contact screw and the hammer. The closer the screw is screwed down on to the hammer the shorter is the distance that the hammer has to travel in its excursions up and down; thus the rapidity of the make and break is greatly increased. The screw must not be screwed down so tightly that the hammer has no room to vibrate, for then the current would become merely a continuous one, and all inductive action would be lost.

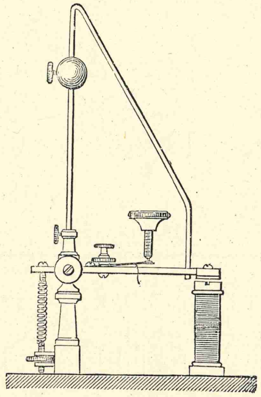

FIG. 46.—ADJUSTABLE INTERRUPTER.

The farther the screw is placed from the level of the electro-magnets, the greater will be the excursions of the hammer and the longer will be the time between make and break. If the screw be removed too far, the spring may not be strong enough to pull the hammer up to it. In such a case no current would pass, as the circuit would be permanently open.

The movements of the hammer can be still further slowed by placing upon it a weight. The arrangement

by which such a weight can be applied is called an adjustable interrupter.

It is composed of a bent metal rod, the two ends of which fit into small sockets on the limb of the hammer. A metal ball can be moved up and down the upright line of this bar. The higher the ball is placed, the more difficult it is for the hammer to work, and the interruptions are thus very appreciably slowed.

The different effects produced by rapid and by slow interruptions will be considered later.

4. **The Secondary Winding.**—This is usually composed of very fine copper wire wound upon a hollow wooden bobbin. There are a great many more of these turns of wire in the secondary than there are in the primary. Many batteries have as many as five thousand turns. The more turns there are, the higher will be the voltage of the currents induced in the secondary. This is therefore another electrical economy, for a very high voltage current can in this way be obtained from a single cell. This secondary coil may be called a "step-up transformer." In many batteries the wooden bobbin carrying the secondary coil is mounted on a sledge, by means of which it can be slid on and off the primary coil.

When this bobbin is pushed right over the primary coil the secondary winding is brought into the varying electro-magnetic field always present round the primary when the current in the latter is being made and broken by the Wagner's hammer. Every time the current is made in the primary, a current flowing in the *opposite* direction is induced in the secondary. When the current is broken in primary, a current flowing in the *same* direction as the primary current is induced in the secondary winding.

Thus rapidly alternating currents are produced by induction in the secondary coil. In addition to this inductive action of primary on secondary, each turn of the secondary also exerts an inductive action upon its neighbours; thus, a very strong current results.

The currents in the secondary can also be still further augmented by the use of the iron core, in exactly the same way as the primary current was.

The type of battery in which the secondary coil slides over the primary is called a sledge coil. This piece of apparatus is very useful, as great variations in the different currents can be obtained.

In some batteries the secondary coil is a fixture over the primary, so that the full effect of the primary is always obtained. In these cases the total current is usually weak, but can be considerably augmented by the use of the iron core.

The circuit of the secondary coil is only completed when the patient is suitably connected with its terminals; these binding screws are indicated by the letter *S*.

The difference between the currents in the primary and secondary coils must be clearly understood. In the primary, the current is a rapidly interrupted current flowing in *one* direction, augmented by the presence of the extra currents produced at break, decreased by the extra currents produced in the opposite direction to the original current produced at make. Such a current may be compared with an interrupted galvanic current, but it is jerky and uneven, now strong, now weak. It has not a pleasant effect upon the patient.

The currents in the secondary coil are regularly alternating—that is to say, at one moment the current is flowing round the circuit in a clockwise direction, at the next moment in a counter-clockwise direction, but the current at break is greater than that at make. Such currents are smoother, more regular, and pleasanter than the primary. It may be here repeated that the currents in the secondary have no direct continuity with the currents in primary. The two circuits are completely separate. The secondary currents are absolutely independent currents induced by means of the varying electro-magnetic field in the neighbourhood of the primary coil.

METHODS OF REGULATING THE CURRENTS

1. **The Primary.**—(*a*) By altering the number of cells.

(*b*) By introducing or withdrawing the iron core.

(*c*) In some batteries the iron core is a fixture in the centre of the primary coil.

In these cases, the inductive action of the core upon the current can be varied by means of a metal tube placed between it and the coil.

The magnetic lines of force cannot penetrate through this metal sheath, so they are completely cut off when the sheath is pressed well home, covering the whole of the iron core. The current in the primary is then at its weakest. To make the current stronger, the metal tube is gradually withdrawn, thus allowing the inductive influence to act between core and coil, and resulting in the production of the extra currents in the primary circuit.

As this mode of regulation is exactly opposite from that in which the iron core itself is movable, it is of the greatest importance that the method adopted in any given battery be known before use on a patient. Otherwise, it might happen that the full strength of the current was suddenly applied, causing much alarm and pain to the patient.

It may here be stated that the position of the secondary coil has no effect upon the primary current.

2. **To regulate the Secondary.**—(*a*) By altering the position of the secondary in relation to the primary. If the secondary is pushed well over the primary, it is brought within the sphere of a large electro-magnetic field, and strong currents are induced in it. By withdrawing the secondary from the primary, the currents in the secondary are weakened.

(*b*) By the use of the iron core, which acts in the same way on the secondary as on the primary.

(*c*) In many batteries, the secondary coil is fixed in relation to the primary coil. This is usually the case when the primary current is weak, and its total effect upon the secondary is not too great for treatments. The secondary current can then only be varied by means of the iron core, or, if this is also a fixture, by the metal sheath.

Common Causes of Trouble in the Induction Coil.—If the induction coil fail to work at any time, it may be for one of the following reasons:

1. The cell may be exhausted; if this is the case, it must be replaced by a new one.

2. The interrupter does not invariably begin to work immediately the current is switched on. Its action can usually be started by very gently tapping the hammer.

3. Frequently it will be found that the contact screw is too far from or too near to the hammer. Judicious adjustment is all that is necessary in this case.

4. The wire spring holding up the hammer may have become loosened, thus not drawing the hammer back to the contact screw when the iron bars have become demagnetised. Care is needed to tighten this spring to the exact amount.

5. Dust and rust on the small metal tongue of the hammer are often sufficient to prevent the passage of the current. This must be removed by careful cleaning with very *fine* emery paper. Oil should never be used on electric apparatus because of its insulating effect.

6. If the battery is in good working order and yet no current is felt by the patient, it is probable that the conducting cords are broken, or their contact with the electrodes is imperfect. A second pair of conducting cords should be always at hand in case of such an emergency.

Method of Registering the Faradic Current.—There is no satisfactory apparatus, comparable with the galvanometer, by means of which the faradic current can be measured in definite units.

The most that can be done in the way of registration is to make use of a means by which the strength of currents used at various times can be compared and recorded.

Such a comparison can be made by noting the position of the iron core in relation to the coils, or the position of the secondary in relation to the primary coil.

Both these positions can be recorded by means of the small scales arranged upon the sledge of the secondary and on the iron core itself.

CHAPTER XX

FARADISM : METHODS OF APPLICATION

The Effect of Faradism on Nerve and Muscle.—The faradic current, whether primary or secondary, exercises its effect on muscular tissue only through the nerves. The electrical impulse acts in the same way as the nervous impulse, provided both nerve and muscle be normal and healthy. The nerve impulse set up by the current is very readily conducted along the nerve, enters the muscle through it, and is rapidly distributed by the branching network of nerve fibres to every part of the muscle. Thus the muscle is immediately thrown into a series of contractions corresponding with the make and break of the current. These contractions are most readily obtained when the electrode is applied directly to the motor point, thus stimulating the main entry of the nerve into the muscle.

If an electrode carrying a fairly strong current is held stationary on the muscle for any length of time, the rapidly interrupted currents keep up such a quick series of contractions that the muscle fibres, not having time to relax before the next command to contract is received, are thrown into a continuous state of contraction, called tetanus. This is an undesirable result when giving treatments, as it causes an exhaustion of the muscle in the following way. With each muscular contraction, the fluids in the muscle, the blood and the

lymph, are squeezed out of it; with the succeeding relaxation, more blood is sucked in. When the muscle is tetanised, this relaxation does not occur; the blood supply is then temporarily cut off together with the due supply of oxygen, and the muscle, so to speak, strangles and asphyxiates itself.

The great benefit of faradism lies in the exercise produced by the muscular contractions set up, the effects being those of all active movements—increase of circulation and nutrition, improvement of metabolism, and permanent strengthening of the muscle.

These effects are particularly valuable in the case of involuntary muscle, such as that found in the walls of the alimentary canal and in the pelvic organs, which are beyond the scope of voluntary exercise.

It is to be clearly understood that the faradic current only stimulates the muscles through the conductivity of the nerves.

When the nerves, through disease and degeneration, have lost the power of conducting impulses, the muscles themselves fail to contract to this form of electrical stimulation. This is because the make and break of the faradic current is much too rapid to produce movement of the more slowly responsive muscular tissue.

METHODS OF APPLICATION OF FARADISM

As there is no danger of producing electrolytic burns with the faradic current, this form of electricity is much less dangerous to handle than the galvanic. In fact, patients and their relatives are frequently allowed to apply the faradic battery after a little instruction.

The following methods of application are in use:

1. **For Skin Stimulation.**—A metal electrode, such as a wire brush or a brass cylinder, is used for the active

electrode. This is applied directly to the skin by the labile method. Being metal, it is not necessary to wet it, as it conducts perfectly when dry. Any moisture which may be present on the skin is generally removed by the application of a little dusting powder. This prevents the skin from conducting the current too readily to the underlying muscles.

The indifferent electrode is a large, flat metal plate, covered with chamois, lint, or flannel. This is well wetted and applied firmly to some distal and insensitive part of the body.

2. **For Muscle Stimulation.**—The labile method is used for reasons already given—that a strong current, if applied by the stabile method, tetanises and exhausts the muscle.

There are two methods by which labile faradism can be applied:

(*a*) **By Means of a Moving Electrode.**—The indifferent electrode is a large flat metal plate, covered with flannel or lint and well wetted. This is to be applied in such a way as to lie over a superficial part of the nerve which supplies the affected muscles. It is to be kept stationary and fixed firmly in position by bandages or sandbags.

The active electrode may be either a metal disc or a roller mounted upon a wooden handle. In either case, the metal part of the electrode must be covered with wet chamois or lint. A very useful electrode can be easily improvised by means of a sponge in a chamois bag, into the centre of which the metal tag of the conducting cord is buried. Even a thick roll of cotton wool can be used for the purpose.

The active electrode, of whatever type is chosen, is to be kept thoroughly wet by dipping it from time to time into a basin of hot, soapy water. The soap is used to make the electrode glide evenly and smoothly over the skin with good contact. It also has the effect of removing grease from the skin and thus allowing a more ready penetration of the current. The treatment is given by rolling or dabbing the electrode up and down on the affected muscles with a current sufficiently strong to produce vigorous contractions. These contractions are most readily produced when the electrode is placed directly upon the motor points. These latter must therefore be carefully picked out when giving treatment for weak muscles.

(*b*) **"Swelling" or "Surging" Faradism.**—This method, named by de Watteville, is a most satisfactory one when applying strong currents over large areas, as, for example, a limb in which all the muscle groups require equal attention.

Both electrodes must be large enough to envelop the muscles under treatment. If the leg is to be treated, one large pad should be wrapped completely round the lower leg, and a second large pad round the thigh, care being taken to avoid short circuiting. The pads, as usual, must be thoroughly wet, and bandaged firmly in position with suitable electrodes. The faradic current is then turned on, weak at first, then gradually increased in strength until the patient is conscious of the pricking sensation. The current must now be rhythmically increased and decreased by regularly and smoothly advancing and withdrawing the secondary coil or the core, as the case may be. These movements must take place sufficiently slowly to produce even muscular contractions and relaxations. This is a very satisfactory and pleasant method of treating large areas with strong currents, for exposure and chilling of the patient is avoided, and concentration of the current is prevented.

Faradism can also be applied by means of large, fixed pads if a metronome or rhythmic interrupter is introduced into the circuit. The interruptions prevent the tetanising effect of the faradic current if they are timed at such a rate as to allow for definite muscular contractions and relaxations.

3. **Stabile Method of applying Faradism.**—This method is occasionally used for the dulling of chronic pains, as in neuralgias where there is no definite inflammation of nerves present. The pads and electrodes are arranged as described under "swelling faradism," but only a weak current applied, as muscular contractions are not required.

In order to produce the sedative effect, the vibrations of the hammer must be made as rapid as possible.

4. **Faradism applied by the Electric Bath.**—Faradism can be applied to the limbs very conveniently by means of arm and leg baths.

The strength of the current must be varied in order to produce contractions and relaxations, and to avoid the tetanising effect. This variation can be produced either by the method described under swelling faradism, or by the introduction into the circuit of a metronome or rhythmic interrupter.

The Rapidity of the Interruptions.—The methods of varying the rate of the interruptions by means of the contact screw and the adjustable interrupter have already been considered.

We must now consider the uses of the slow and rapid vibrations.

Slow vibrations produce more powerful and also more painful muscular contractions than quick ones. For the exercise and development of muscles, the interruptions should be made as slow as the apparatus permits.

Rapid vibrations produce a sedative effect, and are used for chronic pains when definite inflammatory changes are not present.

If the number of interruptions is very great, anæsthesia can be produced. Special apparatus is required for obtaining this effect.

Choice between the Primary and Secondary Currents.—With most of the ordinary batteries on the market the secondary coil is the most satisfactory, because it gives a current with a higher voltage than the primary, and so produces a greater effect on the patient. The differences in the two currents depend to a great extent upon the thickness of wire and the number of turns in the coils. With any individual battery, that coil will generally be chosen which gives the best results.

In addition, it may be said that for superficial muscles and nerves the secondary will be almost invariably used, whereas the primary is frequently recommended in the following cases:

(*a*) In the treatment of deep-lying organs.
(*b*) For electric bath treatments.
(*c*) For hysterical conditions.

CHAPTER XXI

FARADISM: THERAPEUTIC USES

I. General Faradisation.—This method of treatment is ordered for much the same class of cases as general massage.

With it, the whole body is brought under the influence of the interrupted current; all the muscles are thrown into contraction and exercised; all the nerves are stimulated; the internal organs are also affected.

By the muscular and nervous activity set up, metabolism is increased, the circulation is improved and the general nutrition of the body is benefited. This treatment is therefore useful in the following conditions:

Neurasthenia and hysteria.
General debility.
Nervous dyspepsia.
Anæmia.
Rickets, etc.

Technique.—The secondary current is used, weak at first, but gradually increasing in strength as the patient becomes more tolerant.

The patient is arranged as for general massage, being undressed and lying upon a plinth or couch. It is very important to carefully arrange mackintoshes and towels in order to protect the patient's clothing and bed-linen from getting wet.

1. **The Indifferent Electrode.**—This is a large metal plate covered with moistened flannel or chamois leather. It is important that it should be of good size in order to diffuse the current over a large area, and so minimise discomfort. For most of the treatment the patient lies on this, which may be placed either under the dorsal or sacral region.

As an alternative, a flat hot-water tin attached to the battery may be used. The patient keeps the soles of the feet firmly pressed upon this, receiving the treatment in the sitting position.

2. **The Active Electrode.**—This may be:

(*a*) A roller or disc.
(*b*) A sponge.
(*c*) A spongio-pilene pad.
(*d*) The hand of the operator through which the current is conveyed by a bracelet electrode. This method is useful for children and very nervous patients.

In every case, the chosen electrode must be kept wet throughout the treatment with hot soapy water.

The whole body is treated in sections:

1. The patient lies in the supine position with the plate electrode beneath shoulders or buttocks in such a way that firm contact is maintained.

(*a*) **Head.**—While this is treated, the active electrode is held in one hand of the operator and the current conveyed to the patient's forehead and vertex through the operator's other hand. By this procedure the strength of the current can be gauged and the danger of applying an unpleasantly strong current to the head is avoided.

A weak current is used, only just strong enough for the patient to be conscious of the tingling sensation.

Time.—One to two minutes.

(*b*) **Neck.**—The active electrode is moved up and down the sides of the neck and the anterior triangles in order to stimulate the vagus and phrenic nerves. The larynx must be carefully avoided, stimulation of this organ being very unpleasant.

The current must be weak.

Time.—Two minutes.

(*c*) **Arms.**—The active electrode is passed rapidly up and down all the large muscle groups of the upper limbs.

Projecting bony points and large, superficial nerves are to be avoided.

The current used must be strong enough to produce brisk muscular contractions, but not strong enough to cause pain.

Time.—Two minutes each arm.

(*d*) **Abdomen.**—The active electrode is worked with some degree of pressure over solar plexus, stomach, liver, and intestines, producing a kind of electrical massage.

The course of the colon is to be carefully followed from the cæcum to the sigmoid.

A strong current is needed, because the resistance of the abdominal region is always very considerable, especially if constipation and flatulence are present.

Time.—Three or four minutes.

(*e*) **Legs.**—These are treated in the same way as the arms, the production of brisk contractions of all the large muscle groups being aimed at.

Time.—Two minutes each leg.

2. The patient now turns into the prone position in order that the back may be treated. The indifferent electrode is placed beneath the solar plexus.

Back.—The active electrode is pressed firmly up and down the whole length of the back on each side of the spinous processes, so that all the spinal nerves are influenced. The various muscle groups of the back are also to be treated from the cervical to the sacral regions.

Time.—Five minutes.

The whole séance lasts from fifteen to thirty minutes, according to the tolerance of the patient. The treatments are usually ordered every other day.

The good results experienced are a feeling of exhilaration and well-being, increase of appetite, relief of dyspeptic symptoms, and a steadying of the pulse.

II. **Faradism for Wasted Muscles where R.D. is not Present.**—The interrupted current is indicated for the treatment of weak and wasted muscles, always provided that the nerve supplying these muscles is healthy. It will be remembered that the faradic current stimulates muscular tissue, not directly, but through the nerve. When the nerve is damaged and degenerated and unable to conduct impulses, then the muscle fails to respond to the faradic current. This has already been mentioned in the chapter on "Nerve and Muscle Testing"; the subject of Reaction of Degeneration should be revised at this stage. It will be remembered that R.D. occurs after severe lesions of the lower motor neurone, and that there are three important groups of cases in which it is found:

(*a*) Lesions of the anterior horn cells:
  1. Acute anterior poliomyelitis.
  2. Progressive muscular atrophy.
(*b*) Lesions of the nerve trunk:
  1. Section of a nerve.
  2. Pressure on a nerve.
(*c*) Degeneration of the nerve trunk:
  Peripheral neuritis.

In these conditions, where the muscle fails to respond to the faradic current, it has hitherto been the teaching of medical electricians that it is useless to give this form of current, and that labile galvanism alone is indicated until some degree of recovery takes place. The teaching of some authorities is opposed to this tradition, and at several hospitals cases of infantile paralysis with R.D. are treated by faradism with marked benefit.

There are, however, many other cases of weak and paralysed muscles where R.D. is absent, and for which faradism is especially useful; the following list includes some of the commoner cases:

1. All the above-mentioned conditions after the period of degeneration has passed.

2. The weak and flabby abdominal and intestinal muscles so often the cause of chronic constipation and gastric and intestinal atony.

3. The weak and stretched groups of muscles found in connection with the common deformities:

Club foot.
Flat foot.
Scoliosis.
Kyphosis.
Lordosis, etc.

4. Hemiplegia in the flaccid stage and during the stage at which recovery is taking place. In this connection it should be stated that faradism must be stopped at once if any spastic symptoms appear.

Faradism is contra-indicated in all varieties of spastic paralysis, such as the paraplegias, disseminated sclerosis, paralysis agitans, etc.

5. Facial Paralysis.—This condition requires a special paragraph, as there are considerable differences of opinion with regard to the electrical treatment of this form of paralysis.

In some 75 per cent. of the cases the trouble is caused by a rheumatic inflammation of the trunk of the seventh nerve. This, on swelling, becomes compressed in the tightly fitting stylo-mastoid foramen, and thus the function of the nerve is interfered with. In mild cases the swelling may subside before degeneration sets in; in the more severe inflammations damage may occur which results in the usual R.D. In long-continued cases it occasionally happens that a condition of over-contraction, called secondary contracture, of the paralysed muscles takes place.

In the remaining 25 per cent. of cases the damage occurs inside the brain, affecting the upper motor neurone. In such cases the prognosis depends upon the extent of the lesion in the brain. The facial paralysis, which occurs in connection with hemiplegia, usually clears up with considerable rapidity. In all these cases, where the condition results from damage to the upper motor neurone, R.D. does not take place, and the muscles respond throughout to the faradic current.

To sum up, it will be seen that the facial muscles will respond actively to faradism in the slighter cases of rheumatic paralysis, in those cases in which R.D. is gradually disappearing as recovery takes place, and in the cases of cerebral origin. Although in so many cases the faradic current appears to be indicated for treatment, it is, however, a moot question whether it should be used or not.

Some authorities say most emphatically that faradism is always contra-indicated in cases of facial paralysis, because of the danger of overstimulation and secondary contracture. Those who follow this teaching will avoid the use of faradism altogether, and will trust to the interrupted galvanic current. There are some practitioners who go still farther in the matter of precaution and forbid the use of the kathode upon the face when galvanism is being used.

If the faradic current is used for this condition, constant watchfulness is required in order that it may be stopped at once if the slightest signs of contracture begin to appear.

III. **Faradism for the Stimulation of Unstriped Muscle.**—The involuntary muscle of the alimentary canal very readily becomes weak, stretched, and atonic, as the result of sedentary habits, injudicious dieting, anæmia, rickets, etc. In such cases constipation and flatulence occur early, and later a dilated and dropped condition of the various abdominal organs may occur (visceroptosis).

In all such troubles dependent upon muscular weakness, the faradic current is most effective. It has the power of producing vigorous contractions of both the abdominal and the intestinal muscles, resulting in increased circulation, improved nutrition, and permanent strengthening of the said muscles. The treatment may be given labile, by the swelling method, or with metronome interruptions.

IV. **Cutaneous Stimulation.**—In cases where the vitality of the skin is reduced, usually as the result of defective circulation, faradism is very valuable. It assists the healing of chilblains, of chronic ulcers, and of the trophic sores often present in infantile paralysis and other nervous diseases.

Where the circulation especially needs improvement, labile faradism may be used.

Where the cutaneous nerves require stimulation, as in cases of hysteria, the dry skin should be treated by the metal brush electrode.

V. **Hysterical Conditions.**—The anæsthesia, the paralysis, and the aphonia so frequently found in these cases are generally the result of psychic influences rather than of definite organic changes. Therefore any treatments applied should be made as impressive and as formidable as possible. The applications are best applied in a large electrical department in sight of elaborate apparatus.

Anæsthesia.—A very strong current of an unpleasant nature is indicated. This is one of the few cases in which electrical treatment may justifiably be painful. As stimulation of the cutaneous nerves is desired, the skin should be dry and metal electrodes, uncovered by chamois, should be used. If a sufficiently strong current be applied, the patient may be finally induced to admit to an improvement of sensation.

Paralysis.—This is best treated by labile faradism, the current used being strong enough to produce vigorous contractions. The motor points must be carefully located and worked upon.

Aphonia.—When loss of voice is complained of, the sudden application of a strong faradic current will cause contractions of the laryngeal muscles, making the patient involuntarily cry out, and thus producing an obvious cure. Two wet padded disc electrodes are suitable for the application. These are to be brought quickly into position, one on each side of the larynx, with the current running at a considerable strength. No harm will result from a strong shock, as the patient quickly jumps back, thus breaking the circuit. In many cases, one application completes the cure.

In hysterical cases the primary or secondary current may be chosen as seems best. If the primary is very strong, this is preferable, as it is more jerky and unpleasant than the secondary. In many small batteries the primary coil does not produce a sufficiently strong current, and the secondary must therefore be used.

VI. **Chronic Neuralgias.**—In cases of pain along nerve trunks, where no active inflammation is present, and in those cases where dull achings remain long after an acute attack of inflammation has subsided, faradism often has a very beneficial result. For the sedative effect, a small secondary current with very rapid vibrations should be used. Benefit has resulted from both stabile and labile treatments, and each of these may be given a trial.

VII. **Conditions resulting from Defective Circulation.**—As both venous and lymphatic circulations are largely maintained by muscular contractions, it will be apparent that both these will be greatly improved by the vigorous muscular activity induced by faradism, and that conditions resulting from defective or impeded circulation will be benefited by the use of this current. Such conditions are chilblains, Raynaud's disease, œdema due to obstruction of lymph or blood vessels, varicose veins, etc.

Any of the methods of applying labile faradism, already described, may be used: the production of brisk muscular contractions is to be aimed at.

CHAPTER XXII

COMBINED CURRENTS: GALVANO-FARADISATION

Uses.—The use of the combined current, *i.e.* the simultaneous application of galvanism and faradism, was first introduced by de Watteville. He stated that excellent results were obtained by this form of treatment. He argued that the continuous current produced desirable metabolic effects and at the same time threw the tissues into a condition of increased electrical excitability, so that, when the galvanic current was running, the nerves responded more readily to faradic stimulation; thus,

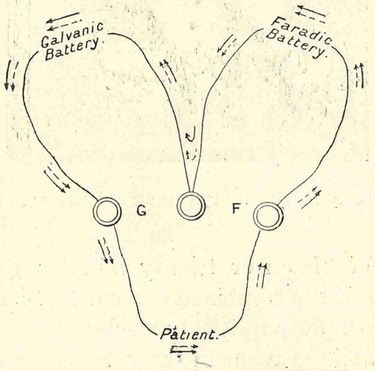

FIG. 47.—DIAGRAM OF CURRENTS IN COMBINED GALVANIC AND FARADIC BATTERY.

greater effects were obtained upon wasted muscles and degenerated nerves by use of the two currents at the same moment than by either or both given separately. The conditions for which galvano-faradisation is indicated are:

1. Weak and flabby muscles without R.D.

2. Paralysed muscles, even when R.D. is present. It will be often found that degenerated muscles will respond more actively to labile galvanism after the application of fifteen or twenty minutes galvano-faradisation than if the combined current had been omitted. Similarly, partially paralysed muscles also respond more readily to labile galvanism after massage of the part than before massage.

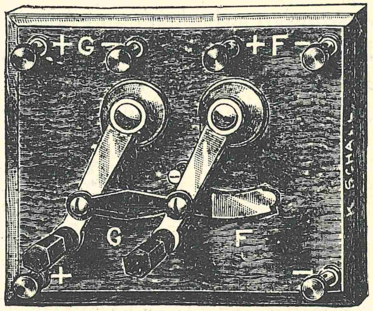

FIG. 48.—DE WATTEVILLE COMMUTATOR

De Watteville Switch.—In order to give the combined current easily, de Watteville devised a switch which goes by his name, and which is usually to be found on combined batteries and galvanic and faradic switchboards. By its means a galvanic or a faradic or a combined current can be transmitted at will to the

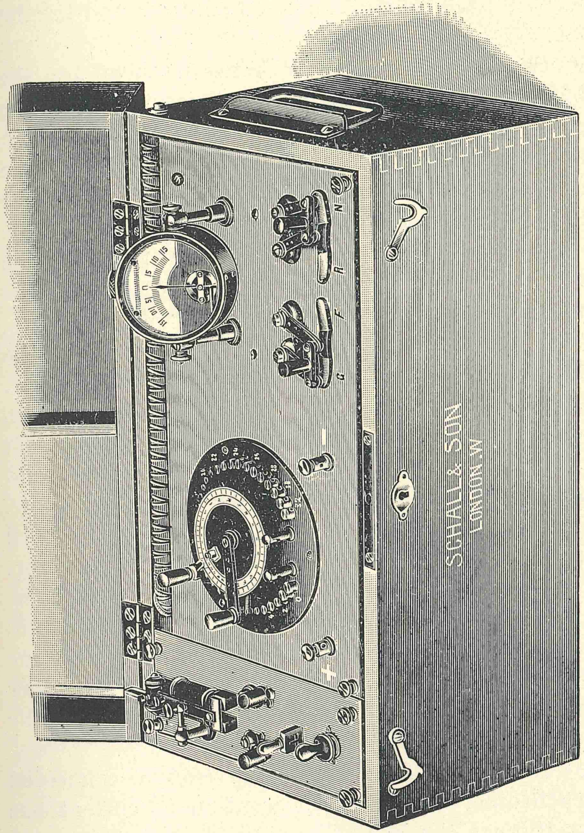

FIG. 49.—COMBINED GALVANIC AND FARADIC BATTERY WITH DOUBLE CELL COLLECTOR AND DE WATTEVILLE COMMUTATOR.

patient through a single pair of terminals, cords, and electrodes.

The accompanying diagram indicates the course of the current taken in the combined galvanic and faradic battery.

The two terminals with *P* between them are the binding screws to which the conducting cords are attached.

When the cranks of the switch point to *G*, the galvanic current is connected with the terminals. Its course should be traced on the diagram. It leaves the galvanic cells at +, passes to the left-hand metal plate, up the crank *A*, thence to the terminal + and through the patient. Re-enters the switch at the terminal —, passes to the screw of the crank *K*, down *K* to the middle metal plate, and back to the galvanic cells at —.

By moving the switch over to the right-hand side, marked *F*, the galvanic current is at once switched off and the faradic current connected with the patient, and this without any alteration of cords or electrodes.

The course of the faradic current should be followed out on the diagram in the same way as was the galvanic.

In order to apply both currents simultaneously, the cranks of the switch must be brought to a standstill half-way between the above two positions, so that one crank is in contact with the metal plate *G* and the other in contact with the plate *F*, neither touching the middle plate.

The galvanic and faradic batteries are now connected with each other in series; the continuous current has to pass through the induction coil and the patient, and the faradic current has to pass through the patient and all the galvanic cells. Thus, both currents are led through the patient simultaneously.

Some combined batteries are supplied with three binding screws instead of the de Watteville key. The middle binding screw serves as a terminal for both currents. The two screws adjacent to the letter *G* are used for galvanism; the two adjacent to *F* for faradism; and the two outside screws are used when both currents are to be given at the same time. In the latter case the galvanic current must pass through the faradic coil on its way to the patient, and the faradic through the cells of the galvanic battery. See diagram.

The question "Which is the more useful, a combined or two separate batteries?" is frequently asked. This depends upon whether the electrical apparatus will have to be carried about to the homes of patients or whether it is for use in the rooms of the masseuse. In the latter case, a combined battery is preferable, especially when fitted with the de Watteville key. It is compact, and both currents are available for treatment with very little re-arrangement of apparatus. Where much of the masseuse's work is done away from home, the combined is less useful, as it is considerably heavier than either type of single battery. Besides which, suppose one patient required only faradism and another only galvanism, the double battery would have to be taken from house to house for each treatment, whereas the single batteries could be left with the patients.

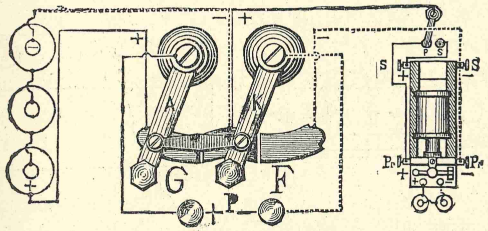

FIG. 50.—COURSE OF COMBINED CURRENTS.

Where the combined battery is not available, it is still possible to give galvano-faradism by means of two separate batteries and three wires.

The anode of the galvanic is to be connected by one wire with the negative of the faradic (if this is marked). This leaves the kathode of the galvanic and the positive of the faradic free, to be attached in the customary way to the patient. The two batteries and the patient are connected in series. That is to say, the whole of the galvanic current passes through the faradic coil on its way to the patient, and similarly the faradic passes through the galvanic cells.

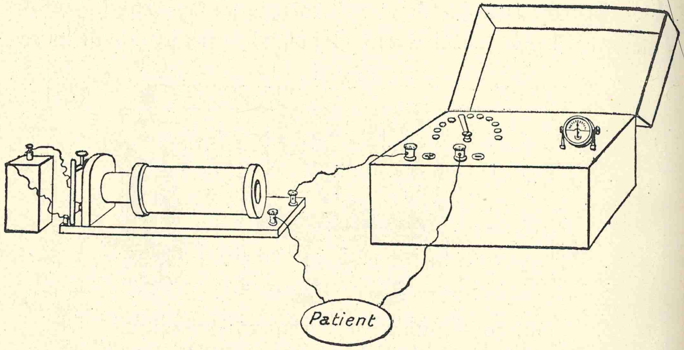

FIG. 51.—GALVANIC AND FARADIC BATTERIES CONNECTED TO GIVE COMBINED CURRENT.

Application.—The combined currents may be given stabile, with the faradic current fairly weak, in order not to produce a tetanus of the muscles. This combined current greatly increases the electrical excitability of nerves and muscles. After it has been running for ten minutes or a quarter of an hour, the treatment should be finished by a labile application given with the movable disc or by means of reversals. Excellent muscular contractions are obtained by this method.

PART III

CURRENTS FROM THE MAIN

CHAPTER XXIII

THE DYNAMO

STRONG currents of electricity, generated at power-stations, are now supplied in all urban and many rural districts for the purposes of lighting, heating, and power. Where the main current is available, it is more convenient to make use of this constant source of supply for medical work than to rely upon primary batteries and accumulators.

Production of the Main Current.—The main current is produced at a power-station by a piece of apparatus known as the dynamo. By means of this any kind of mechanical energy can be converted into electrical energy.

Large districts are usually served by private companies. Many establishments, where much electricity is used, such as hospitals and hotels, are equipped with private dynamos, thus being independent of the public supply.

The Dynamo.—This consists of the following essential parts:

1. A very powerful horseshoe magnet, known as the field magnet, arranged with its north and south poles facing each other, leaving a space between them. From

what has been already said on the subject of magnetism, it will be understood that this space is filled by magnetic lines of force passing from pole to pole.

2. In this magnetic field a coil of wire wound upon an iron core is made to revolve by any mechanical power available. Steam, gas, petrol, and water power are all utilised.

This revolving coil of wire is called the armature. In it electric currents are induced as the coil revolves in the magnetic field.

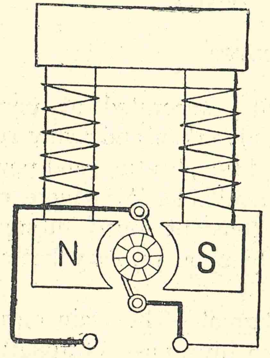

FIG. 52.—SHUNT-WOUND DYNAMO.

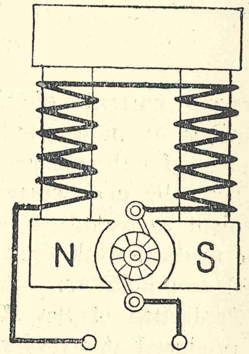

FIG. 53.—SERIES-WOUND DYNAMO.

3. The two ends of the revolving coil of wire are connected with a collecting mechanism through which the current is distributed to the mains.

4. The current produced in the revolving armature is in many cases conveyed round the field magnet before leaving the dynamo for the external circuit, thus automatically increasing the magnetism of the magnet and its inductive power.

Types of Current produced by Dynamos.—The current produced in the revolving armature is always an alternating one.

During one complete revolution of the armature the current produced passes half the time in one direction, the other half of the time in the opposite direction.

Such a complete revolution of the armature is called a " period " or a " cycle," and each cycle is composed of two " phases " or two half-turns. The periodicity of an alternating current may be anything from 40 to 100 revolutions per second for lighting purposes.

The alternating current produced in the armature may be delivered as such to the external circuit; this is frequently found to be the case in scattered districts for reasons mentioned below.

In urban districts the current usually supplied is a direct constant current. This is produced by the same kind of dynamo as the alternating current, the difference being in the collecting mechanism. This is arranged in such a way that the current is delivered to the external circuit in one direction only.

It is unnecessary in a small book of this nature to enter into details of construction.

Voltage of Main Currents.—The two kinds of current used in the mains, the alternating and the continuous, are sometimes also spoken of as the high tension and low tension respectively, as the alternating current is usually supplied in the mains at a very high voltage, whereas the direct current is generally of a low pressure.

The choice of a current in any district turns upon a question of expense.

In rural districts, where the current has to be conveyed for many miles, it is necessary to have copper mains of small diameter for the sake of cheapness. Such cables have a relatively high resistance, and a high voltage is required to overcome this. The pressure may be anything from two thousand to ten thousand volts. A current of such a high pressure may not, by Board of Trade regulations, be supplied to buildings until it has been reduced to 250 V. or less. Now, it is a much easier matter to reduce the voltage of an alternating than a direct current. Hence it will generally be found that in country districts the alternating current is used.

In town districts, where distances are not great, it is of more economy to use copper cables of large diameter which will readily take a current of low enough voltage to be supplied direct to buildings without the necessity of apparatus for reducing pressure. The current may be either direct or alternating according to the requirements of the district. In a great many cases the direct current is supplied, as this is useful for a greater number of purposes than the alternating.

Before making use of the main current for medical work, it is necessary to find out from the Electric Lighting Company the following points:

1. Type of current, alternating or direct.
2. If alternating, of what periodicity.
3. The voltage.

With these data the electro-medical instrument makers can supply suitable apparatus for converting the main currents into currents of suitable voltage for therapeutic work.

CHAPTER XXIV

THE UTILISATION OF THE DIRECT CURRENT

THE direct current from the mains is very convenient for medical use, being for all practical purposes similar to the current produced by the galvanic battery—*i.e.* constant in pressure and continuous or unidirectional. It can be used, after being reduced in voltage, for all the purposes for which galvanic cells are suitable. It can therefore be adapted for:

1. Galvanism.
2. Ionisation.
3. Operating the induction coil.
4. Cautery.
5. Surgical lamps.

It can be utilised by means of two different types of apparatus—(1) the medical switchboard and resistance box; (2) by means of one of the various kinds of earth-free machines now on the market. Of these, the latter is greatly to be preferred for reasons given under the heading, "Dangers of Earth Currents."

The Medical Switchboard.—This will be considered first, as it is a very useful piece of apparatus, provided due precautions are taken. It was in constant use before the introduction of the earth-free machine, and is now found in most electrical departments.

By means of the switchboard, the patient is treated by a regulated portion of the main current through a shunt circuit. This will be obvious by reference to the diagram of the switchboard. The board usually consists of polished wood or marble, upon the front of which are mounted the necessary switches, resistances, and terminals, and at the back are the wires along which the current is directed.

The board is frequently attached to a wall; where portability is required it is mounted upon a trolley.

The current from the main is led direct to the board, to which it is distributed by means of a couple of terminals. It then passes, by means of a complicated series of wires, to the following essential parts:

1. Resistance lamps.
2. The fuse.
3. The shunt rheostat or volt selector.
4. The galvanometer.
5. The induction coil.
4. The de Watteville commutator.
7. The reversing switch.
8. The terminals.

The first three parts mentioned must be considered in greater detail. The remainder in nowise differ from the apparatus already described in connection with batteries and do not require further description.

1. **The Resistance Lamps.**—On a switchboard there are always to be found one or more electric lamp bulbs. The circuit is made, and the main current is turned on to the switchboard by means of the usual type of electric-light switch which will be found in the neighbourhood of the lamp. It must be clearly understood that the current can pass through the main circuit of the switchboard before the patient is connected to the shunt circuit.

These lamps serve a double purpose. First, by their presence they interpose a certain amount of resistance and so reduce the current according to Ohm's law. Secondly, they act as signal lamps, showing at a glance whether the main current is passing through the switchboard or not.

2. **The Fuse or Cut-out.**—After passage through the resistance lamps, the current is then transferred across a piece of apparatus known as the fuse. This appears on the switchboard as a small porcelain box. Its purpose is that of a protection or safety-valve. In it, the ordinary wires of the circuit are disconnected, and the gap bridged across by a wire of tin. Tin very readily fuses when submitted to heat. The tin wire in the fuse is of sufficient diameter to carry the ordinary currents conveyed through the switchboard; if, however, an unexpectedly high current happens to be produced in the mains, the tin wire becomes hot, fuses, and automatically breaks the circuit through the switchboard, thus preventing a fatal shock to the patient.

3. **The Shunt Rheostat or Volt Selector.**—This is the most important part of the switchboard, for by means of it the shunt circuit, to which the patient is connected, is established. It also is the means by which this shunt circuit is regulated in strength.

It consists of a slate core round which some five hundred turns of fine platinoid wire are wound. Its total resistance is about 500 ohms. Upon the surface of the closely wound wire, but not touching it, there is a metal rod. Upon this metal rod a sliding spring is placed in such a way that it makes contact with the turns of wire beneath it. This sliding spring completes the shunt circuit in which the patient is arranged, and by its means more or less of the current can be conveyed to the patient at will.

This rheostat acts upon the principle which Ohm's law enunciates, that the current in a circuit varies inversely with the resistance of that circuit. When the main current enters the rheostat, it is obliged to pass through the total number of turns in order to find its way round the main circuit. Where this main current meets the sliding spring, it then has two possible paths open to it, one along the rheostat and back to the main, the other via the sliding spring, the metal rod, and the patient, this shunt circuit being eventually completed with the main circuit. The current will divide itself between these two paths according to their relative resistances.

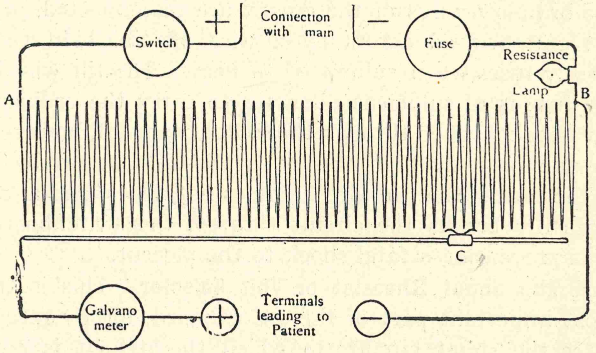
Switch
+
Connection with main
–
Fuse
Resistance
Lamp
A
B
C
Galvano meter
+
Terminals leading to Patient
–

FIG. 54.—DIAGRAM SHOWING RHEOSTAT ON SWITCHBOARD.

If the sliding spring *C* is near the right-hand side *B* (as in diagram), the resistance through the rest of the rheostat and back to the mains is comparatively small in relation to that of the shunt circuit containing the patient. Most of the current will therefore pass along this path of low resistance, and only a very small amount of current will be transmitted through the patient's

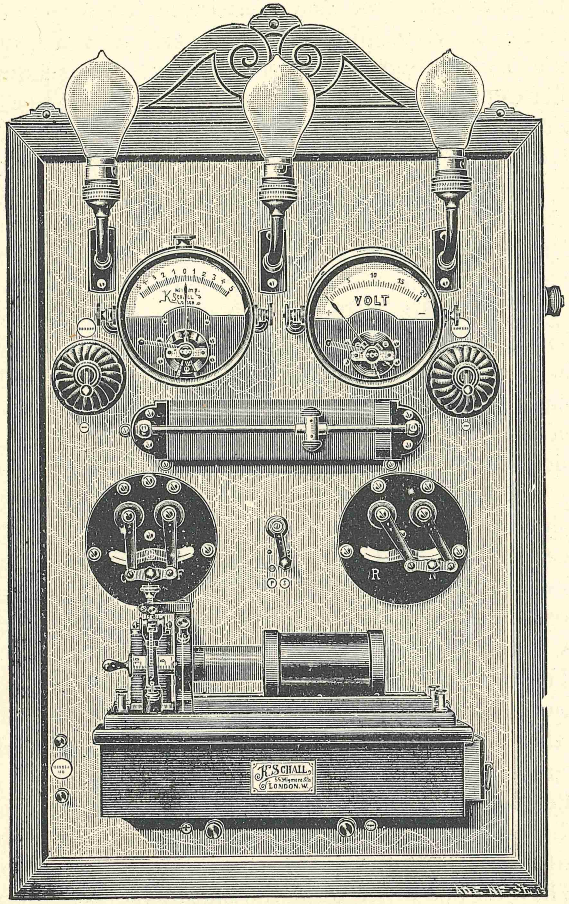
VOLT
K. SCHALL
55 Wigmore St.
LONDON, W.

FIG. 55.—COMBINED SWITCHBOARD.

circuit. As the spring is gradually moved toward the left, the resistance of the circuit through the rest of the rheostat is very gradually increased and a smaller amount of current will pass along it, thus sending a larger quantity through the shunt circuit and the patient.

Such a rheostat gives a very fine graduation of the current, and is a much smoother method of increasing the current than that of the cell collector used with batteries.

Before beginning a treatment, it is of the utmost importance that the sliding spring of the rheostat should be placed in that position which allows of the minimum amount of current to the patient. In switchboards, this is indicated either by letters *S* (strong) and *W* (weak), placed at the ends of the rheostat; or by means of a scale of figures running from 0 to 10 or 12 placed beside the rheostat or marked upon the metal bar. At the end of every treatment the sliding scale must be pushed as far as it will go to the weak end.

Unless these precautions are taken, a patient may at some time be attached to the circuit through which a strong current is flowing, and may thus receive a dangerous shock.

The use of the currents from the switchboard is the same as that from batteries, and nothing need be added to that already said under the methods of application of galvanism and faradism.

Resistance Boxes.—Portable switchboards, arranged in boxes, are supplied by electricians, for either faradisation, galvanisation, or a combination of the two.

They do not differ from the stationary switchboards in principle, but instead of being fixed to the main, they can be attached and detached by means of a flexible cord and wall plug. They can only be used with a direct current of suitable voltage.

In connection with resistance boxes the question of polarity again comes up. It will be noticed that resistance boxes are generally not supplied with + and − signs, indicating the polarity of the terminals. The

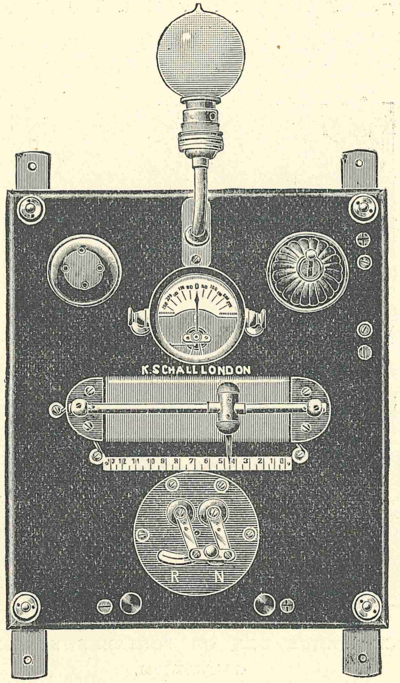

FIG. 56.—GALVANIC SWITCHBOARD.

reason for this is that the polarity of the terminals will vary with the way in which the wall plug is introduced into the wall socket. In the socket, the two wires of the main are hidden; when the wall plug is pushed home, the two wires of the double flexible cord are brought into contact with the two wires of the main, thus completing the circuit through the resistance box.

Now, if the same wire of the wall plug were invariably placed in contact with the + terminal of the socket, then its termination in the resistance box could be marked +, for the polarity would always remain the same. But, practically, the wall plug is inserted sometimes in one position, sometimes in another, and thus the polarity of the resistance box is constantly changed. This apparent difficulty is of no very great consequence, for there are three simple ways by which it may be obviated :

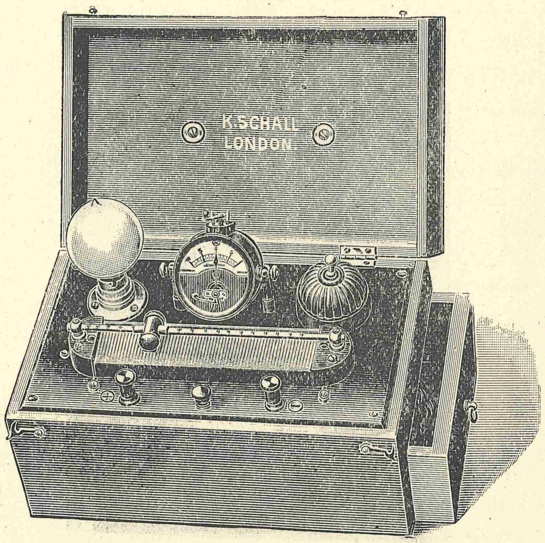

FIG. 57.—RESISTANCE BOX OR PORTABLE SWITCHBOARD FOR GALVANISM.

1. Use pole-testing or litmus paper every time the box is attached.

2. Use pole-testing paper the first time the box is attached. Mark the terminals + and −. At the same time, mark the wall plug and make a corresponding mark on the wall socket. By invariably inserting plug into socket so that these marks correspond, a constant polarity will be obtained.

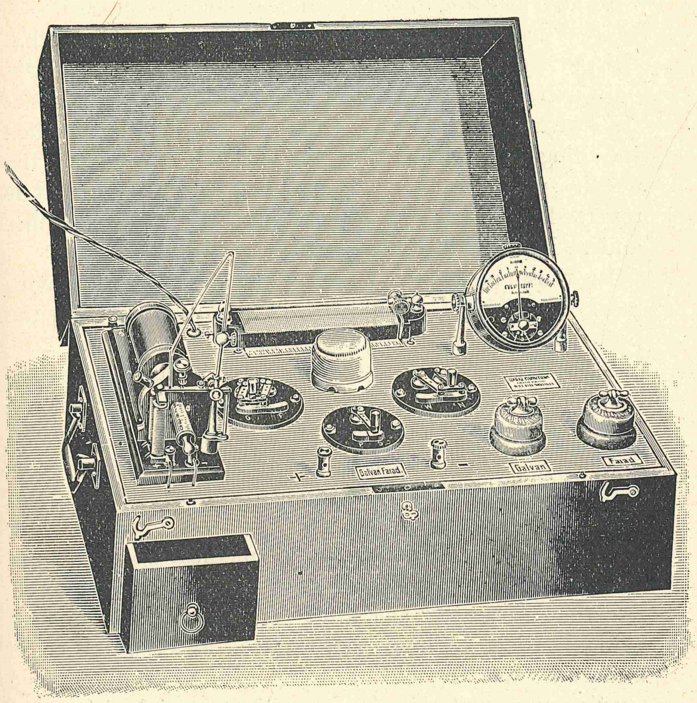

FIG. 58.—RESISTANCE BOX FOR GALVANISM AND FARADISM.

3. Where a galvanometer with normal and reverse scales is provided, this is sufficient to indicate polarity.

Attach the wall plug in such a position that when the circuit is complete the galvanometer needle swings to the right. Now test the polarity of the terminals, carefully marking them + and −.

In order, for subsequent treatments, to be sure that the current is leaving the box by the + terminal, it is only necessary to insert the plug in such a position that the galvanometer needle swings to the right. If when the plug is inserted and the circuit completed the needle swings to the left, it shows that the current is reversed. In order to correct this, take out the plug and re-insert it in the opposite direction.

In those resistance boxes which are supplied with marked terminals, the galvanometer is used to show the position in which the wall plug must be inserted.

Wall Plugs.—In houses wired for lighting purposes, lamp sockets can be used for connecting vibrators, hot-air apparatus, and resistance boxes to the main by means of flexible wire fitted with an adaptor. The current then used is registered by the light meter and priced accordingly. This is an extravagant method where much electricity is used for medical work, because the lighting companies will supply the same current at less than a quarter the price for purposes of medical work, heating, cooking, motors, etc., all of which come under the heading of "Power." In order to arrange for the current at this cheaper rating, special wiring and wall plugs, of different size from the lighting plugs, are attached to a power meter, with which the various pieces of apparatus are used. All such apparatus should be used off the power plugs for the sake of economy, not, as so often thought, because there is any difference in the nature of the currents used for power and lighting.

It may be thought curious that there should be so great a difference in price between the currents used for lighting and power. The point is that power currents are mostly used in the daytime and light at night, and it appears that it pays the electric lighting companies to encourage the use of electricity for power during the day by the cheap rate, when the currents would not otherwise be used to any extent.

CHAPTER XXV

THE DANGERS OF EARTH CURRENTS

In connection with resistance boards and boxes, it is necessary to consider the question, "Is it absolutely safe to use the large currents supplied from dynamos for therapeutic purposes?"

A reference to the diagram of the rheostat will make it clear that the patient is being treated directly by a portion of the main current from the dynamo. Certainly, he is on a shunt circuit, and with satisfactory lamps and resistances it is impossible for him to receive an overdose through the switchboard, unless he be connected while the spring of the rheostat is at strong instead of weak. Nevertheless, when connected with the switchboard, he is also in connection with the dynamo, and the full strength of the dynamo current may reach him by another path than that of the switchboard, that is, by way of the earth. A current travelling from the dynamo through the earth and by means of the patient's body back to the dynamo is called an earth current.

Earth currents arise from two sources:

1. A certain amount of leakage or escape of electricity may take place from the mains into the earth due to defective insulation.

2. In many districts one pole of the dynamo is intentionally "earthed"—*i.e.* directly connected with earth into which electricity escapes.

In either of these cases, the charge which has escaped into the earth will endeavour to find its own level as quickly as possible. That is, it will pass by the simplest path back to the dynamo. If the patient, connected to the dynamo by means of the switchboard, is at the same time also in good electrical contact with the earth, the earth currents would utilise his body as the bridge back to the dynamo. He would thus receive an unmodified current of high voltage which would probably be sufficient to cause his death.

Fortunately, in giving local electrical treatments, such accidents are rare, because in the vast majority of cases the patient is well insulated from earth by the dry wooden floor, carpet, or linoleum which separates him from direct contact with earth.

How he can, by accident, be brought into good electrical connection with earth now remains to be seen and to be avoided.

How Earth Currents may reach the Patient.—1. Through a *wet* wooden floor.

2. Through a damp stone or concrete floor, such as is to be found in operating theatres, etc.

3. Through the metal fittings of water pipes, gas pipes, and electric-light switches, which are always connected directly with earth. The patient must never be allowed to touch *anything* while in connection with the switchboard. It is not sufficient for the patient to avoid contact with such fittings; the operator must also be careful never to turn on a water tap or a light with one hand while holding a connected electrode with the other.

4. Through the hydro-electric bath. Baths, either general or local, if connected with earth by water taps and waste pipes, must on no account be served by the main current through a switchboard. Where these are

used, the patient is in perfect connection with earth, first through the water and then through the metal fittings. Even where the fittings of the bath are insulated, the patient may put himself in connection with earth by turning on a water tap or touching an electric-light switch. Most of the fatal accidents occurring in connection with electrical treatments have resulted from the use of the hydro-electric bath served from the main by means of a switchboard.

In order to avoid such disasters, it should be made an inviolable rule never to give a general hydro-electric bath directly from the main either through switchboard or resistance box, but to use instead some type of "earth-free apparatus."

Earth-free Apparatus.—In view of the dangers of earth currents as already described, medical switchboards and resistance boxes have been very largely replaced of late years by a great variety of electrical machines known as the "earth-free."

The different electro-medical instrument makers have made use of such names as the following for their earth-free apparatus:

The Pantostat.
The Multostat.
The Polytherap.
The Universal Machine.
The Earth-free Universal Apparatus.

In every case the principle of construction is the same, and the various different makes appear to work equally well in practice.

The essential part of the earth-free machine is a motor transformer mounted upon a suitable stand. The motor is driven by the main current. The motor in its turn is used to operate a miniature dynamo; that is, the motor

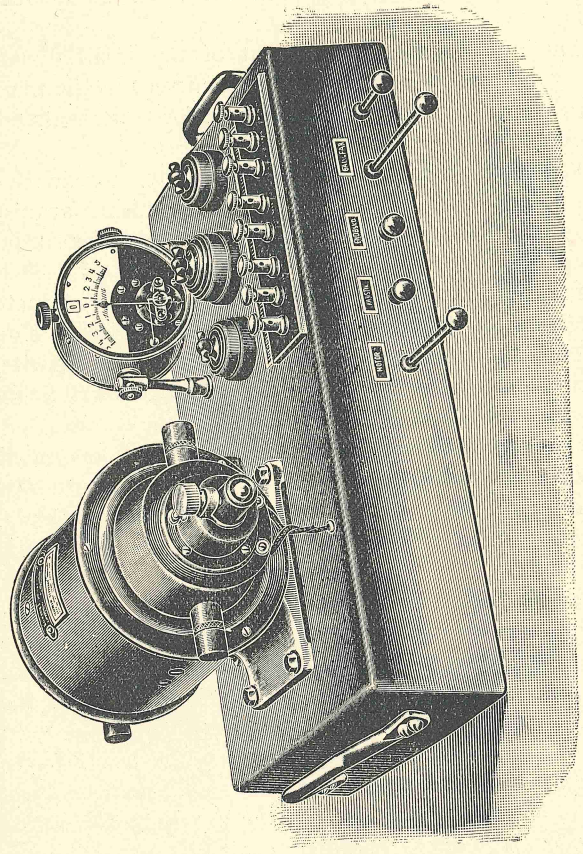

FIG. 59.—EARTH-FREE APPARATUS.

causes a suitably arranged coil of wire to revolve in relation to the poles of a magnet. In the coil of wire, currents are induced, as the coil revolves in the magnetic field.

The newly generated current of the small dynamo has no direct connection with the current in the mains, it is of low voltage, and can be used for treatments with perfect safety.

This current is led off to the various terminals on the stand of the machine, giving galvanism, faradism, the sinusoidal current, and currents suitable for surgical lamps and for cautery.

Upon the stand there should also be a galvanometer, reversing switch, and de Watteville switch. Many machines are also supplied with the commutator (switch) necessary for directing the current to the four-cell Schnee bath.

The practical value of these machines lies in the fact that the patient is only treated by a newly generated and independent current of suitable voltage, and is never in direct connection with the current circulating in the mains. All danger of shock from earth currents is thus entirely obviated.

As there are so many machines on the market, all differing in small details of construction, it is necessary for the student to receive personal instruction in their use.

CHAPTER XXVI

THE ALTERNATING CURRENT

From what was said in Chapter XXIII it will be understood that in many districts the current in the mains is of an alternating character. In such cases, it is generally found that the main current is of a high voltage. By order of the Board of Trade this must be reduced to 250 volts or less before it may be introduced into buildings. The reduction in town districts is usually performed at sub-stations; in rural districts each building is supplied with an apparatus for this purpose known as a transformer.

The transformer works by induction. The principle is as follows:

The alternating main current is carried through a coil of wire wound upon an iron core, like the primary winding of the faradic coil. Upon this same iron core a separate coil is also wound, known as the secondary winding. The alternating current in the primary coil causes the iron core to be constantly magnetised and demagnetised. This varying magnetic field sets up induced currents of an alternating character in the secondary coil. If the number of turns of wire in the secondary are very much fewer than in the primary, the voltage of the secondary current is very much less than that of the original current in the primary. Thus the voltage of the current can be reduced by such an apparatus to a safe figure. This kind of transformer is a "step-down" one. The faradic coil is also a transformer; but in the majority of cases it is constructed to increase the voltage in the secondary winding; it may thus be called a "step-up" transformer.

Although the alternating current introduced into the building is of a reduced voltage after the use of the transformer, it nevertheless still remains an alternating one. An alternating current is perfectly satisfactory for lighting and heating purposes, but it is not so useful for electro-medical work.

It will be understood that the medical switchboard and resistance box used for the direct current would be quite unsuitable for use with the alternating current.

To utilise the alternating current for treatments a machine of the earth-free type is essential. Such a machine acts as a motor transformer in the following way:

The alternating main current operates the motor; the motor causes the coil of a small dynamo to revolve. In this coil alternating currents are induced, but these can be collected by a special arrangement of the collecting brushes as a direct current. This direct current is then conveyed to the various terminals of the stand, and can be used for galvanism, ionisation, faradism, light, and cautery.

When ordering an earth-free machine it is necessary to give the instrument makers exact data as to the type of current, A. or D., with which it is to be used, the voltage, and in the case of the alternating current its periodicity.

The Sinusoidal Current.—The alternating current as described above might also be called a sinusoidal current. This term is used to denote an alternating current of perfectly regular opposite and equal phases; that is to say, the current starting from zero travels round the

complete circuit in one direction, gradually increasing in strength to a given maximum; the strength then wanes regularly and smoothly until zero is reached. At this moment the direction of the current is reversed; it travels round the circuit in the opposite way, but again waxes to a maximum and wanes to a minimum with perfect smoothness. There is never any moment at which the current is suddenly broken or made.

The diagram (or graph) of such a curve would be:

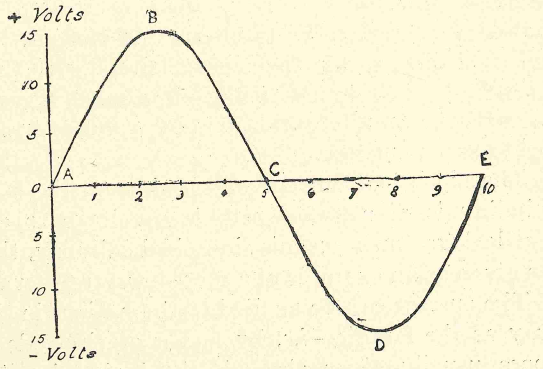

FIG. 60.—GRAPH OF SINE CURVE.

The curve above the zero line indicates a current running round the circuit in one direction gradually waxing and waning; the curve below the zero indicates the current running in the reverse direction, also gradually waxing and waning. Such a curve is known mathematically as a sine curve, thus giving its name to this type of current.

The sinusoidal current is largely used at the present time in place of the faradic current as supplied by the induction coil. The sinusoidal differs from the faradic in its smoothness and regularity; it produces the same effect as the faradic but is much more pleasant in sensation and because of its regularity it can be borne more easily. It is also said that its stimulation more closely resembles the normal nerve impulse than the faradic.

In order to give sinusoidal treatment to the patient it is necessary to have a sinusoidal coil. This closely resembles the faradic coil, but the vibrating armature is absent. An alternating current is led round the primary winding. This alternating primary induces regular and even alternating currents in a secondary winding from which the patient is treated. If the mains are supplied by an alternating current, this may be used directly for the sinusoidal coil. If the direct current is used in the mains, this must first be converted into an alternating one by a motor transformer sold for the purpose.

The sinusoidal current obtained from the secondary winding is of a sufficiently low voltage to allow of medical treatments; this sinusoidal coil may, therefore, be given as an example of a step-down transformer.

The current can be applied to the patient in the same way as the faradic—*i.e.* by means of electrodes. It is more usually given through the hydro-electric bath, either the full bath or the four-cell bath, to be described later.

CHAPTER XXVII

ELECTRIC BATHS

THESE are either general or local, unipolar or bipolar; the galvanism, faradism, or sinusoidal currents are all applied by means of baths.

I. **The General Electric Bath.**—This is an example of a bipolar bath, both electrodes being immersed in the same vessel. It has hitherto been very largely used in the treatment of constitutional diseases, such as neurasthenia, general debility, insomnia, anæmia, rickets, diabetes, etc. In hospitals it is very frequently used for the treatment of children with infantile paralysis where many muscles are affected.

The bath itself should be made of porcelain or glazed earthenware; in some cases wooden baths are used. Metal of any kind is contra-indicated. If a switchboard is used to take the current from the main, the bath must be completely insulated from connection with the earth, because of the danger of earth currents. It is wiser to avoid the use of switchboards altogether for giving the full electric bath. But this is not always possible. Where the switchboard is used, danger can be minimised by knowledge and care.

The waste pipe must be insulated from earth. It should be of rubber. All taps and switches must be out of reach of the patient. The patient must be carefully warned to touch nothing while in the bath. Taps must not be turned on after the patient has entered the bath. If more hot water is needed to keep up the temperature, this must be added by means of a jug.

Large electrodes, one at the head and one at the foot, hang over the edge of the bath into the water. These are usually made of copper, and must be kept bright and clean. They should be arranged in such a way that the patient cannot touch them. Many are now supplied in a wooden frame as a protection. The bath should be supplied with a canvas strap upon which the patient's head can rest. Water at 100° F. or a little hotter is used; this must be prepared at the correct temperature before the patient enters. The patient is allowed the use of a suitable bathing dress, as this makes no difference to the passage of the current. When the patient is

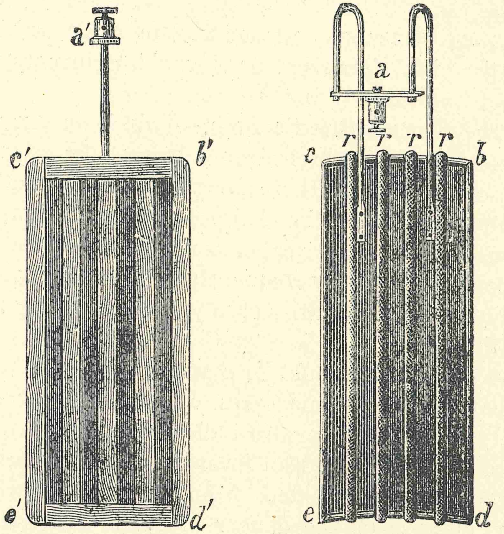

FIG. 61.—PROTECTED ELECTRODES FOR ELECTRIC BATH.

immersed, the current of the type ordered is very gradually turned on. It is increased sufficiently for the patient to be conscious of a pleasant tingling sensation. The length of treatment varies with the individual case. Usually ten or fifteen minutes is enough at the beginning of the course. This may be gradually increased to a maximum of thirty minutes as the condition of the patient improves. At the end of the treatment, the current must be very gradually turned off before the patient leaves the water. A good supply of warm bath-towels must be at hand. After thorough drying, the patient must rest in a warm room for half an hour before leaving. It is very necessary to take great precautions against the possibility of chills.

The disadvantage of the bipolar bath—*i.e.* one in which both electrodes are immersed in the same vessel—is that a large proportion of the current passes directly through the water from pole to pole, and only a small amount penetrates the patient's body. The quantity which the patient receives has been variously calculated as only one-tenth to one-third of the total current passing. Salts and acids should never be added to the water of a bipolar bath, as they increase the conducting power of the water and so reduce the proportion passing through the patient. The current for the full bath is most suitably taken from an earth-free machine or from a sinusoidal apparatus; it can be used from very powerful batteries of dry cells or accumulators.

II. **The Local Electric Bath.**—The local bath is usually monopolar—*i.e.* the vessel in which the limb is immersed contains only one electrode; the indifferent electrode is applied elsewhere on the patient's body either as a pad or as a second monopolar bath. The advantage of the monopolar bath is that the whole current is bound to enter the patient's body before it can reach the other pole; thus no current is wasted, and the total amount received by the patient can be accurately measured.

For the treatment of hands and feet any small vessel of suitable size and shape can be used, provided it is composed of some non-conducting substance such as earthenware, papier-maché, pulp, or wood. Enamel ware may be used, provided it is not chipped or cracked. For large areas the earthenware or porcelain arm and legs baths supplied with Dr. Schnee's outfit are more satisfactory.

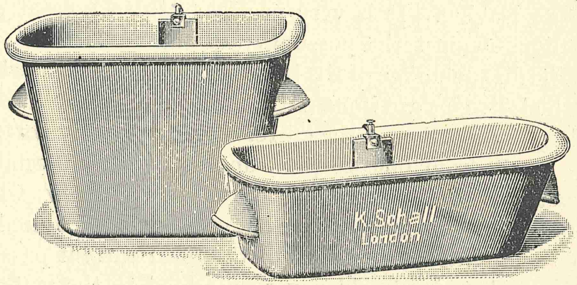

FIG. 62.—LOCAL ARM AND LEG BATHS.

Every type of current from batteries, switchboards, or universal machines can be made use of. Where ionic medication is being given, it is important that the electrode used should be of carbon, which is unaffected by any current.

III. **Dr. Schnee's Four-cell Bath.**—This popular apparatus can be used for general treatment of the whole body or for local applications only.

It consists of the following parts:

1. Two arm and two leg baths furnished with carbon electrodes.

2. Adjustable stands for the arm baths, by means of which the latter can be raised or lowered to suit the patient.

3. A chair upon a wooden or cork mat.

4. A small switchboard or commutator for directing the current as desired.

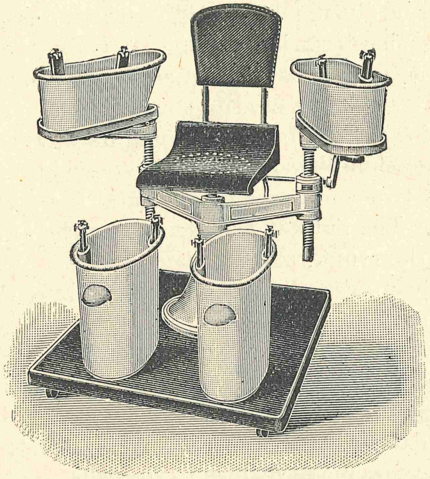

FIG. 63.—DR. SCHNEE'S FOUR-CELL BATH.

The Small Switchboard or Commutator.—This is supplied with:

(*a*) Two binding screws to receive the current from the generator, which may be a pantostat or allied machine, resistance board or battery.

(*b*) Four binding screws for connection with the four cells.

(*c*) Studs and switches, by means of which each cell may be made positive, negative, or neutral at will. Three studs are connected with each terminal; one is marked +, one −, and the third is a blank by means of which the cell in connection with that terminal is put out of the circuit. By adjusting the switches the desired polarity can readily be given to any cell.

Uses of the Four-cell Bath.—(*a*) By means of this apparatus a full bath for the treatment of the whole body can be given. It is used for those cases for which the immersion bath is suitable. It is given as a collection of monopolar baths, one electrode being placed in each cell so that the electric current has to traverse the tissues of the whole body in finding its way from pole to pole. A good method of connection would be as follows: make the two arm baths positive and the two leg baths negative. The current then enters at the arms, passes through the trunk, and leaves at the feet.

The advantages of this form of bath over the immersion bath are obvious:

1. As the patient does not have to undress, there is much saving of time and convenience; there is also less likelihood of chill.

2. The danger of earth currents is completely obviated, as there are no metal fittings to the cells.

As the whole outfit is usually supplied with an insulating stand of wood or cork, the current may be safely taken from the mains by means of a resistance board without fear of earth currents.

(*b*) The Schnée bath apparatus is also particularly useful for local applications.

For example, in treating a case of hemiplegia, one arm and one leg can be immersed in the respective cells, the other two cells being unused. In cases of frost-bite, the two legs can be treated, the arm baths being unused.

For ionisation of the limbs, the apparatus is very

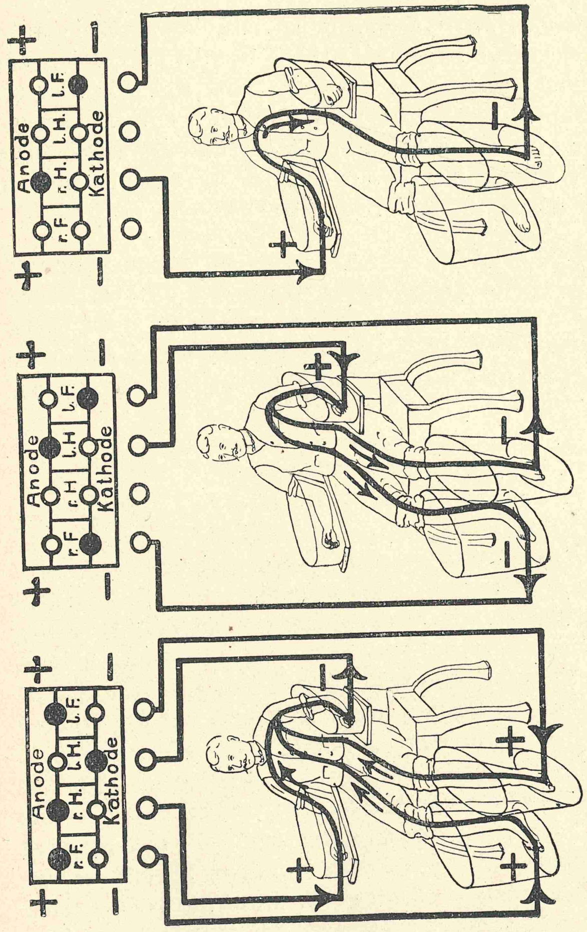

FIG. 64.—VARIOUS METHODS OF DIRECTING THE CURRENT IN THE FOUR-CELL BATH.

valuable, the chief drawback being the large amount of solution required.

In cases where a limb is partially immersed in water for electrical treatment, there is often a cutting and stinging sensation at the water line, which is very unpleasant. This can be overcome either by smearing a layer of vaseline or ointment on the part at this level or by wrapping a strip of lint or cotton wool round the limb where the water-edge reaches.

CHAPTER XXVIII

RADIANT HEAT AND LIGHT

THERE are many ways and a great variety of apparatus by which heat and light can be applied either to the whole body or locally. Unless the student is working in a large institution where elaborate machines are used, the only ones he is likely to meet with are the following:

1. The reflecting lamp.
2. The local light cabinet.
3. The full electric-light bath.

1. **The Reflecting Lamp.**—This is usually a 60 c.p. electric bulb constructed to suit the voltage of the mains with which it is to be used, and attached to a curved metal reflecting hood fitted with a convenient handle. By this both heat and light effects are obtained locally, and the lamp is a useful piece of apparatus for obtaining these effects upon a small area. The lamp is to be held quite close to the affected part and gently moved to and fro as the heat becomes too intense. Some patients find the treatment more comfortable if the part is smeared previously with some harmless lubricant. Iodex is very useful for this purpose in rheumatic cases, as the lamp assists the absorption of the iodine. Tincture of iodine can be used instead of iodex, the tincture being painted on the affected part.

2. **Local Light Baths.**—These are made in many different shapes and sizes, and can be readily adapted to various parts of the body.

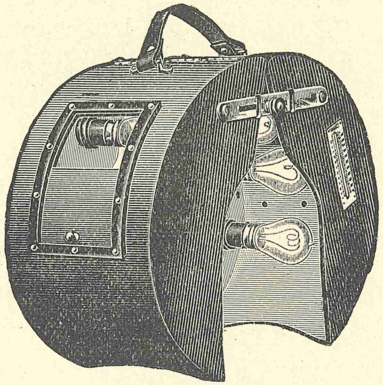

FIG. 65.—SMALL LIGHT BATH FOR LOCAL APPLICATION.

The local bath is usually composed of a brightly reflecting metal case containing six to twelve electric bulbs of 16 c.p.

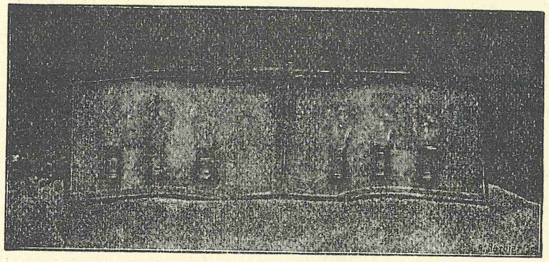

FIG. 65A.

The heat can be regulated as desired, by means of a rheostat which varies the strength of the current.

Care must be taken to avoid scorching of the skin; this is best effected by wrapping the part in a light covering of muslin. The temperature must be raised according to the toleration of the patient; the limit with most baths is about 180° F.

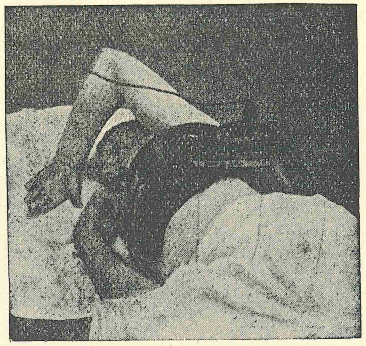

FIG. 65B.

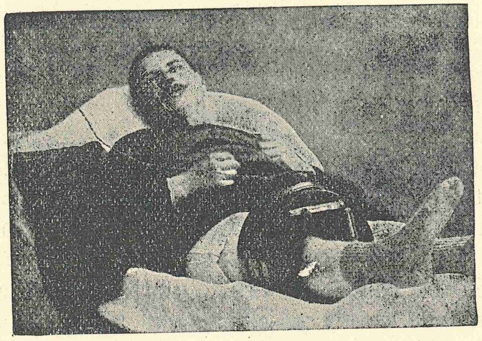

FIG. 65C.

Some baths are especially constructed with a ventilating apparatus to allow as much as 300° F. to be given without discomfort.

After the treatment the current is reduced slightly before the limb is removed.

When the part is taken out, it must be very carefully dried and lightly sprinkled with a suitable dusting powder. Massage and movements may follow if required. In many cases of partial paralysis movements can more easily be performed by the patient after this treatment than before.

3. **The Full Electric-light Bath.**—This is composed of a wooden cabinet fitted with forty or more incandescent lamps, which are arranged so that switches on the outside turn various groups on and off as required. There is also a rheostat externally by means of which the heat can be regulated. A thermometer emerges from the top by means of which the internal temperature is made known.

These baths are made in various forms. Some are arranged with a couch inside upon which the patient lies; others are provided with a chair and footstool so that the patient sits upright. The reclining variety is perhaps more comfortable, but some patients find this oppressive. When closed, the whole of the body is immersed except the head.

Method of Procedure.—The temperature is to be raised to about 100° F. before use, so that time is not wasted after the patient has entered. The patient must be completely undressed and covered only by a thin muslin wrap.

When the cabinet is closed, the opening round the neck is to be loosely packed by a towel.

When the patient is comfortably seated, the current is gradually increased by means of the rheostat to 160° F. or 180° F., according to the tolerance of the patient. During treatment the head must be kept cold and the feet hot. Cold-water compresses applied to forehead and nape of neck ensure the first. With regard to the feet, some baths are supplied with a specially warmed footstool; if this is not the case, hot-water bottles should be applied.

Sweating is increased if the patient drinks freely during the treatment. Hot or cold water, weak tea, imperial drink, or lemonade may be used, according to taste.

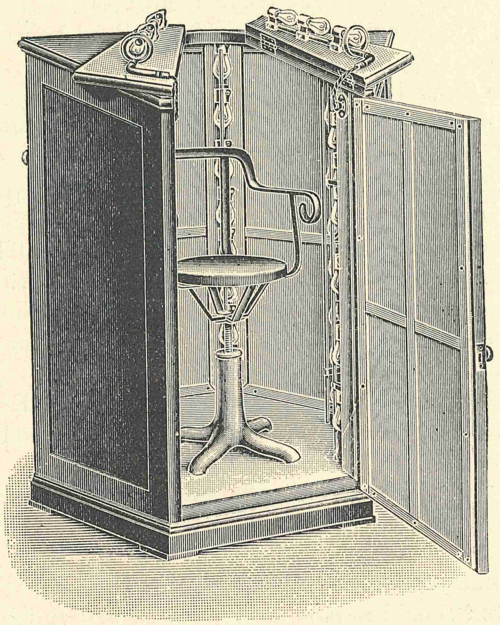

FIG. 66.—THE FULL ELECTRIC-LIGHT BATH.

If at any time the patient feels faint, the pulse becomes irregular and rises above 120, or the temperature above 100° F., the treatment must be stopped at once. If fainting threatens, a teaspoonful of sal volatile in water may be given.

Otherwise, the bath should last from thirty to forty minutes. At the end of that time the patient leaves the cabinet and takes a warm sponge bath with soap, to remove the sweat. She is then wrapped in warm bath towels or blankets, rubbed down, and allowed to rest in the recumbent position for half an hour before dressing.

After the rest a short, brisk " alcohol rub " invigorates the patient and prepares her for the exertion of going home. The " alcohol rub " is a brisk general kneading with eau-de-Cologne or other form of spirit, very popular in America.

It need hardly be said that after the patient leaves the bath, the greatest care must be taken to see that she avoids chills, and that she cools off very gradually. Such baths are not usually ordered oftener than twice a week, as they have a very reducing effect.

Physiological Effects of Heat and Light.—1. Redness of the skin, due to dilatation of the subcutaneous blood-vessels.

2. More or less profuse perspiration, due to vascular dilatation and to the increased activity of the sweat glands.

3. Some acceleration of the pulse. This will become rapid, but should remain strong and regular throughout the treatment. Shortly afterwards, the pulse slows and becomes stronger than previously.

4. A rise of temperature of some 6 or 8 points. This returns to normal after the treatment.

5. Increased elimination of carbon dioxide from the lungs and urea from the kidneys, due to the increased circulation through these organs.

6 Alleviation of pain.

Therapeutic Indications.—1. General intoxications, such as rheumatism and gout. The increased activity of sweat glands, lungs, and kidneys is greatly instrumental in the elimination of toxins.

2. Metabolic diseases such as obesity, anæmia, and general debility. The metabolism is stimulated by the light rays. The number of red blood corpuscles are said to be increased.

3. Nephritis. The increased perspiration relieves the defective kidneys.

4. Œdema. The surplus fluid is drained off by the sweat glands.

5. Joint affections. Rheumatoid and gouty arthritis, stiff joints, and the various forms of synovitis are all benefited by the increase of circulation.

APPENDIX I

THE ACCUMULATOR

THE accumulator or storage cell is a secondary cell in which electrical force is stored up in the form of chemical energy; this chemical energy can be reconverted into electrical energy when required by completing a circuit.

The accumulator in its simplest form consists of two similar lead plates immersed in a solution of sulphuric acid.

In order to "charge" the cell, these similar plates are made dissimilar in order that an E.M.F. or potential difference can be set up.

Charging.—This consists in the passage of a constant current through the cell. Electrolysis of the sulphuric acid takes place, and oxygen is attracted to the plate at which the current enters (*i.e.* the positive plate of the cell) and hydrogen passes to the plate at which the current leaves (the negative plate). The oxygen at the positive plate converts this into peroxide of lead, whereas the hydrogen leaves the negative plate unaffected, and it remains pure metallic lead.

There are now, at the end of charging, two dissimilar plates immersed in an electrolyte of sulphuric acid, giving the essentials of a galvanic cell.

When completely charged, the positive plate is of a chocolate colour (peroxide of lead) and the negative plate grey (pure lead).

It can be now disconnected from the charging current, and can be used as any other chemical cell, the E.M.F.

being set up by the chemical action which can take place between the negative lead plate and the sulphuric acid.

During use, chemical changes occur in the cell resulting in a gradual change of the plates into the original condition of similarity. Charging then has to be performed again in order to produce the dissimilar condition.

The E.M.F of the accumulator is about 2 v., and the volume of the current it can produce depends upon the size of the plates.

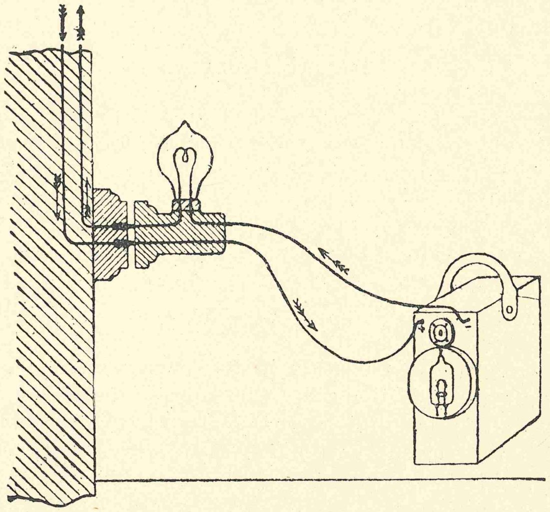

FIG. 67.—METHOD OF CHARGING ACCUMULATORS.

When the voltage falls to about 1·8, it is time for the cell to be re-charged.

The Charging of the Accumulator.—This should be done regularly once a month whether the cell has been used or not, and more frequently if the voltage falls to 1·8 v.

Charging can be done cheaply at any garage, or from the electric lighting main if this is supplied by the direct current. A charging lamp provided with two terminals is necessary; this can be fitted to any electric-light socket.

The positive pole of the main (to be ascertained by pole-finding paper) must be connected with the *positive* pole of the cell; this is usually painted red.

The charging current passes through the accumulator in the opposite direction to the discharging current, and produces the reverse changes; that is to say, oxygen passes to the positive pole, making it into peroxide of lead (chocolate), and hydrogen to the negative pole, reducing it to metallic lead (grey). Charging is complete when the electrolyte becomes milky from the accumulation of bubbles.

The Advantages of the Accumulator.—1. Its high E.M.F. —2 v.

2. Its low internal resistance and large current.
3. Its constancy and length of life.
4. The possibility of repeated recharging.

The Disadvantages of the Accumulator.—1. The need of careful treatment and frequent attention.

2. The readiness with which it becomes damaged.
3. The length of time required for charging.

Its Uses.—It is suitable for spark coils, motors, cautery burners, and small lamps.

A large number of accumulators connected in series will give a direct current of high enough voltage for use with medical switchboards. In such a case there would be no danger of earth currents.

ELECTRICAL THEORIES

Up to the present time it is impossible to answer the question, "What is electricity?" There have already been many theories advanced as explanations of electrical phenomena, three of which may be specially mentioned—the one-fluid theory of Franklin, the two-fluid theory, and the electron theory.

The One-fluid Theory.—This has already been considered in the first chapter. It is only necessary to refer to it briefly here.

This theory supposes that all matter contains an attenuated fluid in the interstices of its particles. So long as the fluid is undisturbed it is impossible to detect its presence.

When in excess in any substance, that substance is regarded as being positively electrified; when a substance is deprived of its due amount, that substance is said to be negatively electrified.

This electric fluid, like water, is regarded as possessing a great desire to find its own level. The positive charge constantly endeavours to escape from the object it is overfilling; the object with a deficit of the fluid craves for more. This fluid is therefore always ready to flow, provided a conductor be provided, from positive to negative. The fluid in motion along a conductor constitutes the electric current.

This theory fell into disrepute chiefly on the ground that there could not be any material fluid which did not increase or decrease the weight of an object when in excess or in deficit.

The Two-fluid Theory.—Franklin's theory was followed by the two-fluid theory, which endeavoured to furnish an explanation of the fact that the weight of a body was not increased or decreased by positive or negative electrification. It presupposed that all matter contained an inexhaustible quantity of the electric fluid, this fluid not being apparent unless disturbed.

By friction or by chemical action it was supposed that this electric fluid was split up into two equal parts, one half going to the positively charged and the other to the negatively charged body. When split into halves, the two portions were regarded as possessing unlike characteristics.

It is needless to say that this theory was soon found to be untenable and speedily discarded.

The Electron Theory.—This theory was introduced about the beginning of the present century, and is now commonly accepted as being the one which most satisfactorily explains electrical phenomena.

It supposes that the electron is the smallest conceivable fragment of electricity, just as the atom is regarded as the smallest particle of matter.

Hitherto, by means of a little scientific imagination we have been able to regard the atom as a minute solid block, and we have visualised atoms as being built up to form matter, just as bricks are united to form buildings. We are now asked by the proposers of the electron theory to regard the atom as being composed of *two* portions, an inner solid and indivisible core encircled somewhat loosely by a number of minute particles called electrons. The solid core is to be considered in a state of positive electrification, the electrons are to be accepted as the units of negative electrification.

When the atomic core is surrounded by its normal supply of electrons, the positive and negative properties combine and the substance in question appears electrically neutral.

When, by such means as friction or chemical action, the electrons are torn from one atom and thrust upon another, the atomic core left without electrons appears positively electrified, whereas the atom upon which extra electrons are thrust appears negatively electrified.

In this state of affairs there is a great disturbance. The atomic core that has had its electrons torn from it is clamouring for them; the excess of electrons thrust upon an atom already duly supplied is being repelled by the electrons rightfully present; and the aggressors are greatly desiring the atom from which they were torn.

Thus, we find the explanation of the fact that like electricities repel and unlike electricities attract each other; the attraction is that of the freed electrons striving to return to a vacant atomic core. These freed electrons will get back if possible. When a conductor is present they travel along it in a stream forming a current of electricity. Even when no conductor is available, the electrons will bridge a gap by means of a spark when two bodies with unlike charges are brought sufficiently near together.

It will be seen that, according to the electron theory, the stream of electrons is regarded as travelling from the object with an excess of electrons, *i.e.* the negatively charged body, to that which has been deprived of electrons, *i.e.* the positive body composed of atomic cores. Thus, the stream must be regarded as travelling from the negative to the positive pole. This is naturally confusing, for, according to the one-fluid theory, the stream has been regarded as flowing from positive to negative.

It might appear, at first sight, that the electron theory would have been simpler if the electron had been considered to be the unit of positive electrification and the deprived atomic core negative. We could then say that the stream of electrons flowed from the positive to the negative pole, thus retaining the old view. Unfortunately, in the early days of this theory a certain fact came under observation which made this nomenclature impossible. This fact was that in the X-ray or vacuum tube under certain circumstances it was possible to actually detect the flight of electrons forming the current, and these electrons were seen to pass from that pole which had hitherto been called negative to the pole hitherto called positive. If, therefore, electrons passed from negative to positive, it was necessary either to regard the pole with the excess of electrons as being negative or else to entirely upset the old nomenclature. It was considered less confusing to the students of electricity to retain the old nomenclature and to bring the new theory into line by calling the electron the unit of negative electrification.

THE MOVEMENTS OF BACTERIA IN RELATION TO AN ELECTRIC CURRENT

Dr. Russ recently read a paper describing his observations on the behaviour of micro-organisms when exposed to a galvanic current. He found that if a number of germs, suspended in a solution of salt, were traversed by a direct current, the germs travelled with the chlorine ions to the positive pole and collected there. On examination a few of these germs were found to be living, but most of them were dead and harmless.

He applied this knowledge to the treatment of septic conditions in the body.

It is necessary that the septic area should be immersed in a bath of salt solution and the positive pole connected. The negative, or indifferent, electrode may be placed on any convenient part. A constant current is then passed of as great a strength as the patient can stand; this will necessarily be small if there is an open wound. After a short time the ulcer or sinus becomes red and congested, and often covered with minute bleeding points. On examination, after the treatment, masses of bacteria are found to have collected around the anode, having presumably been drawn from the septic surface. Most of the cases reported are very successful, healing occurring after a small number of treatments even in old and intractable conditions.

This treatment is not a case of chlorine ionisation; the chlorine ions are not driven into the tissues but, on the contrary, are sent in the opposite direction through the water to the positive pole, and it is assumed that their flow exerts an attractive influence upon the germs, the latter being carried with them to the anode.

Suggested Treatments

The following suggestions may be of use in those cases which are sent for electrical applications with no definite prescription from the doctor. The treatments suggested are those recommended in the various recognised text-books on Medical Electricity.

In any given case, one or more of the methods may be used according to convenience; frequently a choice will be made after several trials of the one which produces the most satisfactory results.

In cases of weak or paralysed muscles, more vigorous contractions will be obtained by electricity if massage is given immediately before; similarly, contractions are more readily produced by labile methods after a short period of stabile galvanism or of the combined galvano-faradism.

Acne	Ionisation with salicyl ions. Incandescent light.
Alopecia areata . .	Ionisation with zinc or copper ions.
Amenorrhœa . . .	Faradism. Sinusoidal bath. Static electricity.
Anæmia	Central galvanism. Sinusoidal bath. Static electricity.
Anæsthesia (Hysterical) .	Strong faradisation of skin with metal brush electrode.
Anterior Poliomyelitis .	1. When R.D. is present: Galvanic reversals. Labile anodal galvanism. Galvano-faradisation. 2. When R.D. has passed: Labile kathodal galvanism. Faradism. Galvano-faradisation.
Aphonia (Hysterical) .	Strong faradism of larynx.
Arthritis	1. Rheumatoid: Salicyl or iodine ions. Faradism for wasted muscles. 2. Gouty: Lithium ions. Faradism for wasted muscles.
Atony of Alimentary Canal Muscles . .	Labile kathodal galvanism. Galvanic reversals. Swelling faradism. Sinusoidal currents.
Atony of Muscle of Bladder . . .	Labile kathodal galvanism. Galvanic reversal. Swelling faradism. Sinusoidal currents.
Baldness	Zinc ionisation.
Boils	Ionisation with zinc needle electrode.
Callosities . . .	Zinc ionisation after prolonged soaking in a zinc solution.
Carbuncles . . .	Ionisation with zinc needle electrode.
Chilblains . . .	Stabile anodal galvanism. Galvanic reversals. Ionisation with iodine, copper, or aconite ions. Faradism for circulation. Sinusoidal currents.
Chorea	Electric baths with rhythmic currents, *e.g.* sinusoidal. Static electricity. For paralysis following chorea: Sinusoidal currents Faradism.
Colitis	Sinusoidal bath. Stabile galvanism, a large electrode in each iliac fossa. Galvanic reversals

Congestion	Stabile anodal galvanism.
Constipation	Sinusoidal currents. Abdominal and lumbar pads with galvanic reversals. Labile kathodal galvanism. Swelling or interrupted faradism.
Contusion	Stabile anodal galvanism.
Corns	Zinc ionisation.
Debility	General or Schnee bath with interrupted galvanic, faradic, or sinusoidal currents.
Diabetes	Schnee bath with sinusoidal currents.
Dilation of Stomach and Intestines	Labile kathodal galvanism. Galvanic reversals. Swelling faradism. Sinusoidal carrents.
Dupuytren's Contraction	Ionisation with chlorine ions.
Dysmenorrhœa	If due to undeveloped uterus—faradism. Membranous dysmenorrhœa—stabile galvanism. Static electricity. Treatments to be given in intermenstrual periods.
Dyspepsia	As for dilated stomach.
Fibrositis	Ionisation with chlorine or iodine ions. Salicyl ionisation. Radiant heat.
Flat Foot	Faradism for invertor muscles. If rheumatic—salicyl ionisation.
Frost Bite	As for chilblains.
Gouty Arthritis	Ionisation with lithium ions.
Hairs (Superfluous)	Electrolysis of hair follicle with negative needle.
Headache	If rheumatic—ionisation of back of neck with salicyl ions. If congestive—stabile anodal galvanism.

Hemiplegia	Labile kathodal galvanism or faradism for the weakest muscle groups. If spasticity supervenes, no treatment is of any avail. Stabile anodal galvanism may be tried.
Hysteria	If blood-pressure is low—static electricity. If blood-pressure is high—high frequency. For paralysis—strong faradism for muscles. For anæsthesia—skin faradisation. For aphonia—faradic stimulation of larynx.
Incontinence of Urine	Faradism to hypogastric and perineal regions. Galvanic reversals with lumbar and hypogastric pads.
Infantile Paralysis	See Anterior poliomyelitis.
Insomnia	Central galvanism.
Intercostal Neuralgia	Ionisation with salicyl ions.
Ischæmic Contraction	Sinusoidal currents. Galvanic reversals.
Keloid	Ionisation with chlorine ions.
Kyphosis	Faradism for back shoulder muscles.
Lordosis	Faradism for abdominal muscles.
Lumbago	Acute—stabile anodal galvanism. Subacute—chlorine, salicyl, or iodine ions. Chronic—chlorine ions; faradism.
Mental Diseases	Sinusoidal bath.
Myositis	Salicyl or iodine ions.
Neuralgia	Anodal stabile galvanism. Quinine or salicyl ions.

NEURASTHENIA	If blood-pressure is high—high frequency. If blood-pressure is low—static electricity. If insomnia present—central galvanism. Electric baths with rhythmic currents.
NEURITIS	Acute—anodal stabile galvanism. Subacute—salicyl ions.
OBESITY	Bergonié's general faradisation.
ŒDEMA	The treatment depends largely upon the cause. If due to obstructed or sluggish venous and lymphatic circulations, faradism is valuable, strong muscular contractions being produced.
OVARIAN NEURALGIA	Electric bath with rhythmic currents. Constant galvanism with hypogastric and lumbar pads.
PARALYSIS OF PERIPHERAL NERVES	If R.D. is present—combined galvano-faradism followed by galvanic reversals or anodal labile galvanism. If R.D. has passed—labile kathodal galvanism and faradism.
PLEURAL ADHESIONS	Ionisation with chlorine ions.
PROGRESSIVE MUSCULAR ATROPHY	As for paralysis of nerves.
PYORRHŒA	Copper ionisation.
RAYNAUD'S DISEASE	As for chilblains.
RHEUMATISM	Salicyl ions.
RHEUMATOID ARTHRITIS	Ionisation with salicyl or iodine ions.
RICKETS	Electric bath with rhythmic currents.
RINGWORM	Zinc or copper ions.
RODENT ULCER	Zinc ions.

SCARS	Chlorine ions.
SCIATICA	Acute—anodal stabile galvanism. Subacute—ionisation with salicyl or iodine ions. Chronic, with dull aching and wasting—faradism with fine vibrations.
SCOLIOSIS	Faradism for muscles on convexity. Chlorine ionisation for concavity (Leduc).
SINUS	Zinc ionisation.
SPASMODIC CONDITIONS	Stabile anodal galvanism.
SPRAINS	Acute stage—stabile anodal galvanism. Subacute stage—salicyl or iodine ionisation. For subsequent weakness—faradism.
STIFF JOINTS	Chlorine ions.
STOMACH	See Atony.
SYNOVITIS	Rheumatic—salicyl ions. Acute—stabile anodal galvanism. Subsequent weakness—faradism.
TABES	Electric bath with rhythmic currents.
TALIPES	Faradism for weak and stretched muscle groups.
ULCERS	Zinc ionisation.
VISCEROPTOSIS	See Atony.
VOLCKMANN'S CONTRACTION	See Ischæmic Contraction.
WARTS	Zinc ions. Magnesium ions.
WRITER'S CRAMP	If spasmodic—anodal stabile galvanism. If paralytic—combined galvano-faradism.

APPENDIX II

THE SYLLABUS OF THE MEDICAL ELECTRICITY EXAMINATION OF THE INCORPORATED SOCIETY OF TRAINED MASSEUSES

Historical.

Nature of electricity.

Theories :—one-fluid theory, two-fluid theory, electron theory.

Production of electricity :—friction, chemical action, induction.

Kinds of electricity :—static, current, induced.

Static electricity :—simple friction experiments ; positive and negative electrification ; attraction and repulsion ; definition and uses of static electricity. (Practical instruction on static machines not included.)

Current electricity :—electric potential ; electric units :— volt, ohm, ampère, milliampère ; Ohm's law ; production of current electricity by chemical action ; demonstration of simple voltaic cell ; polarisation and depolarisation ; constant cells ; wet and dry Leclanché cells ; connection of cells in parallel and in series ; uses.

The galvanic battery :—construction ; cells ; single and double cell collectors ; milliampère meter ; reverse switch ; cords ; electrodes.

Care of battery.

How to use the battery.

Tests for polarity.

Effects of anode and kathode on patient.

Methods of application :—unipolar, bipolar, labile, stabile.

Therapeutic uses of galvanism :—

(1) In painful conditions : neuralgia, neuritis, sciatica, lumbago, etc.

(2) In spasmodic conditions : writer's cramp, spasmodic torticollis, spastic paralysis.

(3) In vaso-motor disorders : chilblains, frostbite, Raynaud's disease, ischæmic contracture.

(4) Ionic medication : elementary chemistry ; elements and compounds ; atoms and molecules ; acids, bases, and salts ; dissociation of ions ; method of treatment ; drugs commonly used and their therapeutic effects ; strength of solutions, and how to make up the solutions.

(5) Application of galvanism for muscles, with reaction of degeneration :—interrupted, reverse.

(6) Theory of muscle and nerve testing (not in practical examination).

Induced Currents

Magnetic and electrical induction.

Construction of induction coil :—Wagner hammer, primary coil, secondary coil.

Types of faradic batteries.

Method of application :—choice between primary and secondary coil, rate of vibration, registration of current.

Uses.—(1) General faradisation.
(2) Wasted muscles without R.D.
(3) Stimulation of unstriped muscle :—constipation, visceroptosis.
(4) Cutaneous stimulation.
(5) Hysterical conditions :—anæsthesia, paralysis, aphonia.
(6) Neuralgia.

Combined batteries.

De Watteville switch.

Uses of combined galvanism and faradism.

Currents from the Main

(1) Continuous or low tension.
(2) Alternating or high tension.

Medical switchboards :—resistance lamps, rheostat, fuse.
Dangers of earth currents.
Varieties and uses of transformers.
The pantostat, multostat, and allied machines.
Sinusoidal currents.
The electric bath.
Dr. Schnee's four-cell bath.
Radiant heat.

QUESTIONS SET IN PREVIOUS MEDICAL ELECTRICITY EXAMINATIONS OF THE INCORPORATED SOCIETY OF TRAINED MASSEUSES

April, 1915

1. Give in full your method of treating a case of acute sciatica by salicyl ionisation.
2. Compare the effects of (1) faradism, (2) galvanism, on muscle.
3. What is meant by ?—
    - i. Electromotive force.
    - ii. Volt.
    - iii. Ampère.
    - iv. Ohm.
    - v. Rheostat.
    - vi. Anode.
4. Describe the character of the current circulating in the secondary coil of an ordinary faradic battery, and explain how it is produced.
5. Give in detail your treatment of a case of poliomyelitis affecting the leg of a child. State your reasons for the method adopted.

6. Describe the treatment by general faradisation. In what cases would you employ it ?

July, 1915

1. State the various kinds of electricity employed in medical treatment, how they are produced and what is the chief characteristic of each.
2. Describe how drugs can be driven into the body through the skin by means of electricity.
3. What is meant by the terms polarisation and potential ? Give an example of polarisation and show how potential is affected by it. What is meant by :—
    - i. Anode.
    - ii. Milliampère.
    - iii. Ion.
    - iv. Electrode.
    - v. Resistance.
4. What electrical reactions would you expect to find in a case of facial paralysis, and how would you treat it ?
5. What kind of electricity would you select for the following cases ?—
    - i. Chronic constipation.
    - ii. Lumbago.

    Give your reason for the selection you make.

December, 1915

1. What do you understand by reaction of degeneration ? Illustrate your answer by describing a case.
2. Explain the shunt resistance rheostat used on medical switchboards.
3. What is Ohm's law ? What is the strength of current you would obtain from ten cells joined in parallel if the internal resistance of each cell is 4 ohms and the electromotive force of each cell is 1 volt and the external resistance in the circuit is 40 ohms ?
4. Give an account of the method of treating a chronic rheumatic joint affection with salicylic ions.

March, 1916

1. Describe an ordinary induction coil.
2. What is meant by the terms ?—
    - Internal Resistance.
    - External Resistance.
    - Depolarisation.
    - Connection in Series.
    - Connection in Parallel.
3. What precautions would you take to avoid an electric burn ? In what forms of treatment are they likely to occur ?
4. Describe the treatment of a patient suffering from sciatica with salicyl ionisation.

July, 1916

1. Describe in detail your mode of procedure in the treatment, by zinc ionisation, of a deep wound in the axilla.
2. You are asked to apply ionic treatment to a knee and derive the current from a switchboard connected to the main. You have arranged your pads in the usual way. On attempting to apply the current, the galvanometer refuses to register and the patient feels nothing. What might have happened and what steps would you take to investigate and, if possible, remedy matters ?
3. Define the following : Electrolyte, base, salt, rheostat, induction coil, electro-motive force, Ampère, ion.
4. Describe the essentials of machines of the Pantostat type. What is meant by saying that such machines are "earth-free" ?

November, 1916

1. Describe briefly the essential characters and properties of each of the following forms of electric current : Direct, Faradic, sinusoidal, alternating.

2. What are the commonest reasons for failure to work, of :—
    - (*a*) A Faradic battery,
    - (*b*) A Galvanic battery ?

    How would you remedy them ?
3. An electric bath is ordered for a child with infantile paralysis. Describe exactly how you would proceed to give it. What precautions are necessary ?
4. What is understood by ionisation ? Name any three ions that might be used, and state which pole you would use in each case, giving reasons for your answer.

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January, 1917

1. Describe the structure and principal working parts of :—
    - (*a*) A Galvanic battery,
    - (*b*) A Faradic battery.
2. What electrical treatment would you suggest for a case of osteo-arthritis of the knee ? Describe the method used.
3. Define electrolyte, salt, series-cell connection, electromotive force, polarisation and Leclanché cell. Describe the latter fully with diagrams.
4. Give the advantages of the electric bath as a method of general electrical treatment. What precautions are necessary ?

April, 1917

1. Explain the shunt resistance rheostat used on medical switchboards.
2. What are the differences between a monopolar and a dipolar electric bath ? In what class would you put the Schnée four-cell bath ?

3. Define (*not describe*) :—
   - (*a*) Connection of cells in series.
   - (*b*) Connection of cells in parallel.
   - (*c*) Polarisation.
   - (*d*) Electrical induction.
   - (*e*) Alternating current.

4. In injury to the Ulnar nerve, at what points would you be ordered to place the electrodes to stimulate the affected muscle ?

July, 1917

1. Define :—
   - Electrolyte.
   - Base.
   - Acid.
   - Salt.

   Fully describe an induction coil.

2. How would you give a direct-current bath for the whole of the upper limb, as for Brachial Neuritis ? What precautions would you take, and what difficulties and dangers might arise ?

3. Define the terms :—
   - (*a*) Electro-motor force. ✓
   - (*b*) Current.
   - (*c*) Resistance.

   And show how they depend upon one another. 0

4. Name different forms of cells. Describe any one of them.

November, 1917

1. What is Ohm's Law ? How does the knowledge of it help in practical work ? 0

2. Explain (and describe by diagram) the course of the current through an ordinary galvanic switch-board. 0

3. Describe briefly the principles of Ionic Medication.

4. How would you use the constant current if ordered for the treatment of a case of injury to the musculo-spiral nerve ? What precautions would you take ?

February, 1918

1. Explain how you would give Faradism for paralysis of the muscles of the arm and shoulder.

2. Describe simply and explain the uses of two of the following :—
   - (*a*) Milliampère-meter. 0
   - (*b*) Metronome Interrupter.
   - (*c*) Shunt Rheostat. 0

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3. When treating a patient with a current derived from the main supply, why do you take the precaution of preventing contact between him and earth ?

4. What electrical methods are in use for causing a muscle to contract and relax rhythmically ?

June, 1918

1. What is meant by polarisation of a cell ? What means are taken to prevent its occurrence ?

2. How do you test for polarity, and how would you show whether the current supplied from your wall-plug was alternating or constant ? +

3. Describe the different methods of giving electrical treatment to a case of facial paralysis.

4. What precautions would you take in giving an electrical treatment to prevent the production of an electrical burn ?

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Printed by Hazell, Watson & Viney, Ld., London and Aylesbury.

Pierce/59931

NOTES ON
GALVANISM
AND
FARADISM

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LONDON

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